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SOME ASPECTS OF THE SALT REQUIREMENTS OF RICE PLANTS DURING VEGETATIVE STAGE [1]

HSIEH FENG YUAN

WITH EIGHT TEXT FIGURES

Espino (1920) found excellent growth and development of rice seedlings, 30 to 40 days of age, when they were grown in a complete and balanced 4-salt solution. Older rice plants grown in a similar solution produced "white tips" and dried leaf tips. These results seemed to indicate that the mineral nutrition or salt requirements of rice plants in the seedling stage may be different from those during vegetable stage. Hence this work was conducted to determine the salt requirements of rice during the vegetative stage.

Because of the excellent growth and development of the young rice plants, 30 to 40 days of age, in Espino's [2] 4-salt solution type A, this culture solution was used as control and other solutions were prepared by modifying the proportions of the various salts. Espino's 4-salt culture solution is prepared by using 1 part KH_2PO_4, 1½ parts each $(NH_4)_2SO_4$ and $Ca(NO_3)_2$, and 4 parts $MgSO_4$ with a total concentration of 0.002 gram-molecule of all the salts taken together per liter.

Review of literature

Kellner (1884) was perhaps the first to conduct experiments on rice in culture solution. He observed that in the early stage of development, the plant grew better in the culture solution that contained ammonium sulfate than in one which received potassium nitrate. He found later that the combination of these two forms of nitrogen was more beneficial to the plant than was either form of nitrogen alone.

For young lowland rice plants, Espino (1920) obtained similar results. In complete 3-salt solutions of Shive's (1915), Espino

[1] Thesis presented in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Botany, University of the Philippines. Experiment Station contribution No. 1435. Prepared in the Department of Agricultural Botany under the direction of Professor Rafael B. Espino.

[2] For facility of reference, this complete and well-balanced culture solution for rice seedlings is here designated as Espino's 4-salt solution type A.

failed to obtain normally developed rice plants during the seedling stage. In these solutions, nitrogen was supplied to the young plants only as $Ca(NO_3)_2$. Excellent growth was, however, obtained with proper salt proportion when ammonium sulfate was added to KH_2PO_4, $Ca(NO_3)_2$ and $MgSO_4$, and the usual trace of iron. This suggested that young rice plants required the ammonium ion.

In a more critical study, Espino and Estioko (1931) obtained similar results. But aside from $(NH_4)_2SO_4$, which was found by Espino (1920) and by Espino and Estioko (1931) to be good for young rice plants, NH_4NO_3 was found also good for this plant (Palisoc, 1928). In fact for young rice plants in culture solutions, Palisoc (1928) observed that NH_4NO_3 was the best, followed by $(NH_4)_2SO_4$ with $NH_4H_2PO_4$ as the poorest. Apparently $NH_4H_2PO_4$ was the most unsuitable, because it caused drying of the tips of the leaves. A new culture solution nutritively better than Espino's best 4-salt solution type A was found by Palisoc. This contained 1 part KH_2PO_4, 4 parts NH_4NO_3, 2 parts $Ca(NO_3)_2$, and 4 parts $MgSO_4$ with a total concentration of 0.00275 gram-molecule of all the salts taken together per liter.

Espino (1920) eliminated NO_3-nitrogen from the solution by replacing $Ca(NO_3)_2$ with monocalcium phosphate ($Ca(H_2PO_4)_2.H_2O$), but supplied the other salts, so that the culture medium formed contained KH_2PO_4, $Ca(H_2PO_4)_2.H_2O$, $(NH_4)_2SO_4$, and $MgSO_4$, and the usual trace of iron, as $FePO_4$. The results showed that the best solutions in this NO_3-free set of cultures gave about as good effects upon the young rice plants as the best ones which contained both the NH_4- and the NO_3-ions. The NO_3-free complete culture media, however, also produced a marked drying of older leaves and of the tips of the young leaves, which indicated that "these young rice plants required, at least within the range of these experiments, not only the ammonium ion but also the nitrate ion" (Espino, 1920). Gericke (1930) could not subscribe to this conclusion. He states that he has proved conclusively that the young rice can thrive in nutrient solutions composed of three salts, with NO_3 but without NH_4.

Fearing that the failure to obtain normally developed young rice plants when NO_3-free solutions were used might have been due to the severe toxic action of the $Ca(H_2PO_4)_2.H_2O$ which was substituted for $Ca(NO_3)_2$, Espino and Estioko (1931) made further culture tests. To eliminate the NO_3-nitrogen in the original Espino's 4-salt solution type A, $CaSO_4$, $CaCl_2$, $Ca(H_2PO_4)_2.H_2O$

$CaHPO_4.2H_2O$, or $Ca_3(PO_4)_2$ was substituted for $Ca(NO_3)_2$. A 3-salt solution and Espino's original culture solution were also tested for purposes of comparison. The results confirmed Espino's (1920) earlier finding that a complete culture solution containing nitrogen only as nitrate was inadequate for young rice plants since the plants were stunted in growth and extremely chlorotic. It was further revealed that nitrogen when present only as ammonium was also inadequate for the young plants because although apparently tall and with rather dark green leaves, the plants deprived of NO_3 always suffered from drying of the older leaves and the tips of young leaves.

Thus, it was once more shown that for a normal growth and development of young rice plants, both NH_4- and NO_3-ions should be present in complete culture solutions. This finding was later corroborated by the researches of Robbins (1923) and of Dastur and Malkani (1933). Dastur and Malkani found that the absorption of NH_4-ions decreased with the age of the plants, whereas the intake of NO_3-ions, though very little in the early stages, increased as the plants grew older. These workers are of the opinion that the differences in the rates of absorption of the two forms of N-ions by the rice plants "may be assigned to the differences in the permeability of protoplasm at different stages of growth". Incidentally, they also found that the rates of intake of NH_4- and SO_4-ions by the rice plants were unequal.

The tolerance of young rice plants to relatively large amounts of $MgSO_4$ in complete culture solution was first observed by Espino (1920). But only four to five parts of this salt have so far been tried. To determine the limit of this tolerance, Espino and Palisoc (1931) conducted further studies and found that better developed plants were produced when the $MgSO_4$ in the original Espino's best 4-salt solution was increased eight times. A new culture solution was, therefore, found containing 1 part each KH_2PO_4, $(NH_4)_2SO_4$, and $Ca(NO_3)_2$, and 32 parts $MgSO_4$ with a total concentration of 0.00875 gram-molecule of all the salts taken together per liter.

Martin (1939), in his study of the physiological disorder known as "white tip" of rice found that the "greatest benefit from the antagonistic action between magnesium and calcium occurred with the magnesium: calcium ratios of 1:1 or 1:3 when calcium and magnesium were present in concentrations of 27, 81, or 243 p.p.m. of each element".

Gericke (1930) tried to distinguish the growth of rice "caused by a given quantity of an essential element absorbed in the early growth period, from that growth associated with the absorption of the element during the entire life of the plant". He showed "that for growth of rice, potassium, nitrogen, and iron are required either in larger quantities or for longer periods of time, than the other elements". On the other hand, Gericke (1930) observed that the absence of one or more of the elements, Ca, Mg, P, and S, "after initial exposure of the rice plants to the complete nutrient solutions, did not have any pronounced harmful effect on the development".

From these observations, Gericke (1930) concluded "that there is no experimental evidence extant to warrant the assertion that all plants require the same essential elements". Moreover, "the actual salt requirement of rice cannot be determined by growing plants to maturity in any so-called complete nutrient solution, however compounded" (Gericke, 1930).

Dastur and Malkani (1933) claimed that the results from the culture solution method employed by Gericke "do not afford quantitative data as to the intake of salt". For excellent growth of higher plants Hoagland (1937) called attention to the need of balanced salt proportions and proper total concentration of culture solutions.

Various workers report the influence upon rice plants of so-called trace elements, such as Mn, B, Cu, and Zn. The beneficial effects of Mn upon rice were reported by Loew and Sawa (1902), Nagaoka (1903, 1904, 1906) and Aso (1907). Recently Castillo (1941) found 0.0232 gram per pot of two rice plants as the best both in the yield of grain and of straw. Roxas (1911) found that $MnSO_4$ at the concentration of M/1000 improved the growth and development of rice plants. Jimenez (1925) obtained good growth of the plant at the concentration of 0.22 per cent, whereas at higher concentrations $MnSO_4$ was harmful.

Tokuoka and Morooka (1936) obtained an increased yield of rice up to 22.3 per cent when boron as $Na_2B_4O_7$ was added to loam soil in pots at the rate of 0.02 to 2 p.p.m. But toxic effects were evident at the concentration of 40 p.p.m. They retarded the growth of rice plants and interfered materially with the tillering and heading. When applied to Lipa clay loam, Castillo (1941) found boron beneficial at the rate of 0.0232 gram per pot of two plants. Roxas (1911) found that at M/100,000, $Na_2B_4O_7$ improved the growth and development of rice.

Roxas (1911) noted that $ZnSO_4$, at M/1000, was good for rice. Tokuoka and Morooka (1938) obtained satisfactory growth of rice at a concentration below 1000 p.p.m. in the soil and 0.5 p.p.m. in the culture solution. They noted, however, that $ZnSO_4$ applied in larger amounts was harmful as it checked the growth of the plant.

Roxas (1911) found also that Cu as $CuSO_4$ at M/1000 was injurious to rice, but half this concentration was beneficial. In complete culture solution, Tokuoka and Morooka (1937) found that $CuSO_4$ applied at the rate of 20 p.p.m. increased the yield of grain, but above 20 p.p.m., it reduced the yield. They also observed that at 100 p.p.m. no yield was obtained, and at 200 p.p.m all the plants died 24 days after application. The optimum rate of application which gave a very good yield of grain was found to be 0.005 to 0.01 p.p.m. Adding a small amount of $CuSO_4$ in irrigation water caused a marked increase of yield of rice (Harrison and Ayyar, 1917). Ishizuka (1940) reported that rice grew well until the Cu content of the top had reached the "concentration of 100 gamma per 1 g of air-dried substance, regardless of the supply of nutrient solution."

The beneficial effects of Cu to rice when present in nutrient solutions in amounts ranging from 0 to 20 p.p.m. were noted by Tokuoka and Dyo (1930) and by Castillo (1941) in pot cultures. Tokuoka and Dyo also observed that in small amounts, Cu produced a gain in yield of grains, with 0.005 p.p.m. giving the maximum yield. At 0.5 p.p.m., however, the plants were rendered sterile, and at 1 p.p.m., the plants were killed before reaching maturity. Castillo reported that mixing two, three, or four trace elements, Mn, B, Zn, and Cu, seemed to be generally more suitable for upland rice than applying the four elements singly or separately.

Gile and Carrero (1916) found that young rice plants, when grown for ten days in Fe-free culture solutions, become chlorotic and had leaves that dried at the tips. They observed that the newly formed leaves were almost pure white, very thin, and generally withered soon.

The minimum amount of $FePO_4$ for young rice plants in Espino's 4-salt solution was determined by Gines (1928) who found it to be 30 to 135 p.p.m. He explained this rather large quantity as due to the rather low insolubility of $FePO_4$ suspensions used. Gines found too that the other iron salts he employed could also supply the element to the young rice plants.

Gericke (1930) observed that the absence of iron in nutrient solution caused young rice plants to die prematurely. Even the three-

month old rice plants when grown in culture solutions without iron became chlorotic. From the results of his experiment, Gericke was led to the belief "that rice has a low absorptive capacity for iron".

Jacobson (1925) found that the pH values of the solutions changed from an average of pH 5.0, before rice plants were grown in them, to an average of pH 3.0 after the plants had been in the solutions for three days. He noticed that the pH value remained practically constant after 24 hours, and the decrease in pH value was more marked during the night.

Mitra and Phukan (1929) studied the effects of hydrogen-ion concentration on rice grown in Knop's solution and found that root lengths had a steady increase with the higher pH values. The development of roots was good above pH 6.0, but below this value, the growth was not normal. The highest root growth was attained at pH 7.9 and the lowest, at pH value of 3.3, which was found extremely toxic to the plant. For normal growth and development of young rice plants, Dastur and Winifred (1938) found that the pH values ranging from 6.4 to 7.0 were the best. Gericke (1930) observed that pH values ranging from 5.7 to 6.7 were the best for rice.

MATERIALS AND METHODS

Plant

Germination. Lowland rice plants, variety Ramai, were grown from seeds which were first soaked in water for twenty-four hours, and then spread between folds of wet blotting paper for initial germination. With plumules and radicles out, the germinating seeds were spread on a piece of cheese cloth which was stretched and tightly tied over a wide-mouthed glass jar filled with tap water up to the rim, so that the cheese cloth just touched the surface of the water. Occasional addition of water was necessary in order to maintain a certain level in the jar. The jar together with the seedlings was exposed to the sunlight.

When the shoots were about five centimeters tall, healthy and uniformly developed seedlings were selected for use in the cultures. Two seedlings were inserted into the holes of paraffined cork stoppers and held in position by means of small pieces of absorbent cotton. To keep the culture solution and the roots in darkness, the culture bottles were wrapped with two layers of paper-an inner layer of carbon paper and an outer layer of Manila paper.

Seedling stage. To prepare the young rice plants for culture tests during the vegetative stage, the plants were first allowed to grow for thirty days in Espino's 4-salt solution type A contained in culture bottles with a capacity of 250 ml. This solution was found to be well-balanced for the seedling stage of the rice plant. It contained one part by volume of KH_2PO_4, one and a half each of $Ca(NO_3)_2$ and $(NH_4)_2SO_4$, and four parts of $MgSO_4$, with a total concentration of 0.002 gram-molecule of all the salts taken together per liter. The usual trace of iron as ferric phosphate was added. Frequent renewals of the culture solution were made.

Vegetative stage. At the age of thirty days, or about the end of the seedling stage, the plants were transferred to larger culture bottles containing complete culture solutions and made up of salts in different proportions (tables 1 to 8). The plants were grown in these culture media for forty-two to sixty-eight days, or during the vegetative phase of the life of the rice plants.

Solutions employed

Single-salt stock solution. The salts used, KH_2PO_4, $Ca(NO_3)_2$, $(NH_4)_2SO_4$, $MgSO_4$, KNO_3, $Ca(H_2PO_4)_2$, NH_4NO_3, and $CaSO_4$ were first prepared singly in M/1 or M/10 with distilled water employed as solvent. All of these salts were "Baker's analyzed".

Iron phosphate. The iron phosphate was prepared according to the recommendation of Livingston (1919) as follows: one liter of 0.04 molar solution of KH_2PO_4 was placed in a 2-liter bottle. A weak solution of $Fe(NO_3)_3$ was added and then stirred until no more precipitate was produced. Distilled water was then added nearly to fill the bottle, and the mixture was shaken and allowed to stand until the precipitates settled down at the bottom and the liquid on top became clear. This clear liquid was then carefully siphoned off without disturbing the precipitates, and the bottle was again filled with distilled water. This process of alternate shaking and siphoning was done several times so as to wash the $FePO_4$ suspension free from KNO_3 and any excess of $Fe(NO_3)_3$ that was added. Finally, distilled water was added to make the volume of the ferric phosphate ($FePO_4.2H_2O$) suspensions two liters and to produce a concentration of about 0.02 molar.

Salts of trace elements. The trace elements were prepared singly and separately in 0.002 M concentration. One milliliter of each solution was then diluted with distilled water to make one liter.

One ml. of each trace element, when added to a liter of the culture solution, produced a concentration of one p.p.m. of the combined salts in the culture solution.

Vitamin B_1. One small glass tube containing 15 mg. of vitamin B_1 prepared by Winthrop Chemical Company, Inc., under the name of "Betaxin" brand of thiamine chloride (synthetic crystalline vitamin B_1 hydro-chloride) was dissolved in 1,500 ml. of distilled water. It produced a solution with a concentration of 0.01 g. or 10 mg. per liter. Three concentrations, 0.1 mg., 0.05 mg., and 0.01 mg., were employed.

Culture solution. The culture solutions were prepared according to the salt proportions and total molar concentrations indicated in tables 1 to 8. Trace elements, vitamin B_1, and $FePO_4$ suspensions were added to the culture solutions, as required by the experiment. The suspensions added were not considered in determining the total concentration of the solution.

The pH of culture solutions. For adjusting the pH value of culture solutions, one per cent solution of NaOH and one per cent solution of HCl were prepared. The final test was determined with a pH indicator equipment.

Replication, care of cultures, and renewal of solutions

Each culture was run in three or four replications. Whenever possible, the cultures were directly exposed to the sunlight on a portable table which was run back and forth on four iron wheels. To keep the cultures from rain and dew, the table was kept under shelter on the approach of rain and during the night. In order to provide the rice plants during the vegetative stage with culture solutions of about the same qualities, that is, with about the same salt proportions and total molecular concentrations, the solutions in most sets of cultures were renewed at the end of every week. No doubt more frequent renewals would have produced better results, but to do so was very difficult, if not impossible. In experiments 1 and 2, renewals of culture solutions were made oftener-every four days.

EXPERIMENTS AND RESULTS

Descriptions of experiments

In all experiments the young lowland rice plants used were first grown for thirty days in Espino's 4-salt solution type A. Then elev-

en sets of cultures were tried, some simultaneously, and each set was considered an experiment. Set 3 consisted of three lots, so that actually thirteen sets of cultures or experiments with different objects were conducted.

Experiment 1. The relation to vigor and physical injury of rice plants during the vegetative stage of addition of a trace element, Mn, B, or Zn, to Espino's 4-salt solution. This set of cultures was started on August 25 and ended on October 27, 1938. Rice plants during the seedling stage were transferred to 1-liter porcelain tumblers supplied with Espino's 4-salt solution type A. Owing to lack of culture bottles of suitable size, some of the cultures were carried out in somewhat smaller bottles, but with suitable control.

Trace elements, Mn, B, and Zn, were added singly and separately in varying amounts at the rates of 5, 10, and 15 p.p.m., and a trace of iron, as $FePO_4$, was added to the culture medium at the rate of one ml. per liter. At the end of the experiment, the plants were observed for physical injuries and then were harvested.[3]

Experiment 2. The effects upon the growth and development of lowland rice plants during the vegetative stage when $MnSO_4$ were added to three new 4-salt solutions. This set of cultures was begun on February 18, 1939, and ended on April 27, 1939. Three 4-salt culture solutions with the component salts, KH_2PO_4, $Ca(NO_3)_2$, $(NH_4)_2SO_4$, and $MgSO_4$, in the proportions of 1:1:1:5, 1:1:2:4, and 1:2:1:4, were used. Each culture medium was supplied with $MnSO_4$ at the rates of 5, 10, and 15 p.p.m. For comparison Espino's 4-salt solution type A with and without Mn was also tried. Whenever it was required, the $MnSO_4$ was added to the solution at the rate of 10 p.p.m. The plants were harvested and experimental data, as averages, gathered.[4]

Experiment 3. The effects of adding to the three 4-salt solutions trace elements, either singly or in certain combinations upon rice plants during the vegetative stage. This set of cultures was started on July 15, 1940. It consisted of three 4-salt culture solutions, which contained salt proportions of 1:1-1/2:1-1/2:4, 1:1:1:5, and 1:1:2:4. With the exception of the control cultures, the 4-salt solutions were again supplied with trace elements, either singly or in combinations. Each trace element was applied at the rate of

[3,4] The experimental data are on file in the Department of Agricultural Botany.

10 p.p.m. On September 21, 1940, the cultures were harvested and experimental data gathered.[5]

Experiment 4. Addition of vitamin B_1 (thiamin) to four 4-salt solutions in relation to the growth and development of rice plants during the vegetative stage. This set consisting of sixteen cultures was started on September 19, 1940. The salt proportions, total molecular concentrations, and other treatments given are indicated in table 1. To each of these culture solutions, vitamin B_1 was added in three concentrations, namely, 0.1, 0.05, and 0.01 mg. per liter of culture solution.

On October 31, 1940, when the plants were forty-two days old, the cultures were photographed (fig. 1) and then harvested. The experimental data gathered under each of the criteria of results employed, together with other pertinent data, are recorded in table 1.

Fig. 1.—Rice plants during the vegetative stage grown in Espino's 4-salt solution in four different 4-salt solutions, each supplied with increasing amounts of vitamin B_1. Photograph by Photographic Division, College of Agriculture.

Experiment 5. Comparative effects of direct or diffused sunlight upon the growth and development of rice plants during the vegetative stage when grown in four 4-salt solutions. This set of cultures was started on September 19, 1940. The exact salt proportions, total concentrations, and other treatment given the plants are recorded in table 2. One set of four cultures was kept in diffused light, while another set consisting of the same kind of cultures was exposed to direct sunlight. On October 30, 1940, all the cultures were photographed (fig. 2) and then harvested. The experimental data obtained are recorded in table 2.

Experiment 6. The effects upon growth and development of rice plants during the vegetative stage of varying the pH values of a new 4-salt solution. This set was started on September 19 and

[5] See footnotes 3 and 4.

was harvested on October 31, 1940. It consisted of seven triplicate cultures and contained the principal salts as follows: 0.00025 molar each of KH_2PO_4, $(NH_4)_2SO_4$, and $Ca(NO_3)_2$ and 0.00125 molar $MgSO_4$ with a total concentration of 0.002 gram-molecule of all the salts taken together per liter. With the exception of the control (culture IV), the initial solution reactions of the different cultures were adjusted by adding either HCl or NaOH. Further adjustment was made once a week or when renewal of solution was made. When the plants were forty-two days old, the cultures were photographed (fig. 3) and afterwards harvested (table 3).

Fig. 2.—Rice plants during the vegetative stage grown in Espino's 4-salt solution and in three other 4-salt solutions each with a total concentration of 0.002 gram-molecule (of all the salts taken together) per liter. Cultures *a-d* were exposed to diffused sunlight; and *e-h* to direct sunlight. Photograph by Photograpic Division, College of Agriculture.

Experiment 7. The effects upon the growth and development of rice plants during the vegetative stage of adding $FePO_4$ in varying amounts to a new 4-salt solution. This set of cultures was started on September 19, 1940, and ended on October 31, 1940. It consisted of five triplicate cultures to which iron as $FePO_4.2H_2O$ was added in varying amounts ranging from one to four ml. per liter. For comparison, Espino's 4-salt solution type A was included. At the end of the experimental period, the cultures were photographed (fig. 4) and then harvested (table 4).

Experiment 8. The influence of volume of solution upon the growth and development of rice plants during the vegetative stage

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when grown in a new 4-salt solution. In this set of cultures, bottles of different sizes, ranging from 250 ml. to 2500 ml. capacity, were filled with culture solutions. This set consisted of four triplicate cultures. It was started on Septemebr 19, 1940, and ended on October 31, 1940. When the plants were forty-two days old, the cultures were photographed (fig. 5) and then harvested (table 5).

Experiment 9. Comparative effects upon rice plants during the vegetative stage of 4-salt solutions with different salt proportions and with different total molar concentrations. This set of cultures was started on September 19, 1940, and ended on October 31, 1940. It consisted of sixteen triplicate cultures with salt proportions and

Fig. 3.—Rice plants during the vegetative stage grown in a 4-salt culture solution supplied with Mn and Zn 10 p.p.m. each and with varying pH values, ranging from 3.91 to 7.04 (*a* to *g*). Photograph by Photographic Division, College of Agriculture.

total molar concentrations as given in table 6. When forty-two days old, the plants were photographed (fig. 6) and afterwards harvested (table 6).

Experiment 10. The effects of varying the amounts of $FePO_4$ upon daily changes in pH value of a 4-salt solution and upon the growth and development of rice plant during the vegetative stage. This set of cultures was started on October 20 and ended on December 18, 1940. Culture I received no iron and was used as control. Culture II received 1 ml. of $FePO_4$ per liter a week and its pH reaction was adjusted every day at 6.5. Cultures III, IV, and V received

1 ml., 3 ml., and 6 ml. of ferric phosphate, respectively, per week. Culture III received 1 ml. of the solution of iron on the first day; IV received 3 ml. a week, 1 ml. being supplied every other day; and V received 6 ml. of iron, supplied every day at the rate of 1 ml. With the exception of culture II, no adjustment of solution reaction was made in the rest of the cultures. The changes of the values of the different solutions were determined daily for seven days. At the end of the experimental period, the cultures were photographed (fig. 7) and afterwards harvested (table 7).

Fig. 4.—Rice plants during the vegetative stage grown in a 4-salt culture solution supplied with Fe in varying amounts ranging from 1 ml. in *a* and *b* to 4 ml. in *e* with Espino's 4-salt solution type A as control. Photograph by Photographic Division, College of Agriculture.

Experiment 11. Comparative effects upon rice plants during the vegetative stage of 4-salt and 3-salt culture solutions. This experiment was started on October 20, 1940. It consisted of six triplicate cultures. The exact salt proportions employed are recorded in table 8. The initial pH values of the solutions were determined and the results are also given in table 8. Culture I contained the new 4-salt solution to which was added Mn and Zn at the rate of 10 p.p.m. each. Cultures II (Espino's 4-salt solution) and III received no trace elements. Cultures IV to VI received trace elements at the

following rates: 0.002 gram $MnSO_4$, 0.0017 gram $Na_2B_4O_7$, 0.0008 gram $ZnSO_4$, 0.0006 gram $CuSO_4$, and 0.014 gram iron sulfate per liter of the culture solution. Culture V contained Gericke's (1940) basic formula, consisting of KNO_3, $Ca(NO_3)_2$, $Ca(H_2PO_4)_2$, and

Fig. 5.—Rice plants during the vegetative stage supplied with 4-salt solution containing Mn and Zn 10 p.p.m. each, and grown in different amounts of the solution, ranging from 2.5 *l.* in *a* to 0.25 *l.* in *d*. Photograph by Photographic Division, College of Agriculture.

$MgSO_4$ in the proportion of 10:1:1:1. Cultures III, IV, and VI, each contained three main salts in the proportions as indicated in table 8. On December 10, 1940, the cultures were photographed (fig. 8) and harvested (table 8).

Criteria for results

In this study, the results of eleven experiments of thirteen sets of cultures are expressed under the following criteria:

External appearance of plants. The external appearance of the plants was noted from time to time especially at the time of harvest. Any physical injuries, especially marked changes in the color and drying of leaves, discoloration of roots, etc., were noted and recorded. Before the plants were harvested, the cultures were photographed.

Height of plant. At the end of each experimental period, the plants were removed from the cork stoppers, and the height of the plants from each culture was measured from the base of the culm to the tip of the tallest leaf.

Fig. 6.—Rice plants during the vegetative stage grown in different 4-salt solutions. Photograph by Photographic Division, College of Agriture.

Length of roots. The length of the roots in each culture was determined by measuring the longest root from the basal end of the culm to the tip.

Number of tillers. The number of tillers in each culture was counted and recorded.

Dry weight of tops. After being harvested, the tops were severed from the roots. The tops of each culture were wrapped with paper, labeled, and placed in an electric oven to dry to constant weight.

Dry weight of roots. When the tops of each culture were severed from the roots, the latter were also wrapped in paper and dried to constant weight in an electric oven with a temperature of about 105°C.

Dry weight of tops and roots. The dry weight of the tops and of the roots from each culture was added. The sum is here considered as the dry weight of the whole plant.

DISCUSSION OF RESULTS

External appearance of plants

An important confirmation of Espino's (1920) finding was that the plants in all the cultures during the seedling stage were quite uniform in growth and development. The plants were green and showed no apparent sign of physical or morphological injury. This healthy appearance of the plants continued until about twenty to

Fig. 7.—Rice plants during the vegetative stage grown in a modified Espino's 4-salt solution supplied with increasing amounts of Fe, and with or without adjustment of the pH values of the solutions. Photograph by Photographic Division, College of Agriculture.

thirty days after the seedling stage, when the youngest furled leaves of some cultures appeared dull white. In some other cultures, the newly formed leaves were whitish green or occasionally brownish green. In either case, they gradually and finally turned green again starting from the basal part of the leaf upward. In a few cases, the white leaves turned green, simultaneously from the apex and from the base towards the middle of the leaves. In some cultures,

however, the tips of the thin and transparent whitish green or brownish green leaves dried and the so-called "white tip" injury appeared.

As the plants grew older, drying of old leaves began to show in several cultures. But the plants that were grown in the 2.5-liter bottles, as well as those in the 1-liter bottles with the reaction of the solution daily adjusted to pH 6.5 never showed any signs of abnormality. Their leaves remained green throughout the experiment.

Fig. 8.—Rice plants during the vegetative stage: *a* in the new 4-salt solution; *b* in Espino's 4-salt solution, and *c*, *d*, and *f*, in 3-salt solutions in which N was present only as NO_3. Culture *e* also contained N only as NO_3 but from salts $Ca(NO_3)_2$ and KNO_3. Photograph by Photographic Division, College of Agriculture.

Effects of trace elements

Previous research studies, mostly with pot and field cultures, revealed the beneficial effects upon the growth and yield of rice plants of certain trace elements, especially Mn, B, Zn, and Cu. The failure of the rice plants during the vegetative stage to grow and develop normally in Espino's 4-salt solution, and the frequent appearance of the "white tips" of rice, might have been due to the absence of all or any of these trace elements in the solution. In fact, no literature dealing with the reactions of rice plants to the secondary essential

elements, when they are in the vegetative stage of their development was available.

Examination of the data on hand revealed that the addition of Mn or B to Espino's 4-salt solution improved the growth and development of the rice plants during the vegetative stage in most of the cultures tried, especially in the production of dry matter of the whole plant. Under the criteria of dry weight of top and dry weight of the whole plant, the only culture that failed to show significant statistical difference from the control was one that received 5 p.p.m. of $Na_2B_4O_7$. Addition of Zn also failed to give the plants any significant improvements of growth over the control, and it was worthy of note that the yields of roots of the cultures that received any of the three trace elements, Mn, B, or Zn, all showed insignificant differences from the yield of roots of the control.

Additional data gathered show the favorable influence of Mn on the growth and development of rice plants in the vegetative stage. Although the difference was not much, Espino's 4-salt solution with 10 p.p.m. $MnSO_4$ produced more dry weights than those obtained from the same solution but without the trace element. With the use of three new 4-salt solutions one showed no significant improvement in growth of the plants over the control. The other two new 4-salt solutions were not only more suitable for rice than the control but produced more dry matter when Mn was added to the solutions.

The additions of the trace elements to each of the three 4-salt nutrient solutions, either singly or in certain combinations, produced results that were not consistently beneficial to the rice plants during the vegetative stage. Even if judged by general appearance, a comparative study was very difficult because the plants looked very much alike.

Bad weather was probably largely responsible for the rather uniform slender development of the plants. These cultures were run from July 15 to September 21, 1940, a period not only of rain but of several typhoons. Although the plants were placed under shelter during inclement weather, the effect of the weather upon the plants was bad because the plants were not able to do their normal photosynthetic work. Hence, their growth was rather abnormal.

In spite of the somewhat uniform stand of the plants, the experimental data obtained from them might perhaps throw some light on the comparative nutritive values of the trace elements. When comparisons were made, some of the test cultures gave statistically better yield of top and of the whole plant than the corresponding con-

trol. For instance, the cultures that received Mn, Mn + B, Mn + Cu, Mn + B + Zn, and Mn + B + Zn + Cu were significantly better than the control, the original Espino's 4-salt solution. One test culture with Mn + Zn was better than the corresponding control culture, a new 4-salt solution. And lastly, the two test cultures that proved to be better than the control were those that contained Mn + B and B + Cu.

It seems possible to select the promising treatments on the basis of the number of repetitions of good results as shown by the data obtained.

As regards the leaf injury called "white tips" of rice, it was of interest to note that the control cultures, that is, those that had no trace elements, produced leaves that somewhat resembled the "white tips", although in some cases no injury occurred, except drying of the tips of some leaves. Moreover, even the test cultures that received trace elements singly or in certain combinations, after their roots were placed in the solution for some time, invariably also produced the malady. The chlorosis of the young leaves, however, disappeared as the plants grew older. It seemed quite evident that the temporary appearance of the "white tips" of rice could be neither due to the absence nor the presence of the trace elements in the culture media.

From the data obtained, it was evident that the addition of Mn and B at certain concentrations to Espino's 4-salt solution improved the growth and development of rice plants during the vegetative stage, and that the combination of Mn + B when added to certain 4-salt solutions also proved beneficial to the plants. No evidence pointed to any of the trace elements having anything to do with the formation or the disappearance of the "white tips" of rice.

From the data obtained from the experiments, the most promising cultures in each table [6] were selected and presented below:

CULTURE NO.	KH_2PO_4	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$MgSO_4$	TRACE ELEMENTS	TOTAL CONCENTRATION
VII (table 3a)	1	1½	1½	4	Mn + Cu	0.002
VIII (table 3b)	1	1	1	5	Mn + Zn	0.002
VI (table 3c)	1	1	2	4	Mn + B	0.002

In connection with the study of culture solutions containing vitamin B_1 (table 1) and that of cultures to show the influence of

[6] The tables referred to are on file in the Department of Agricultural Botany.

diffused and direct sunlight (table 2), the three cultures were compared. The solution which contained one part each of KH_2PO_4, $(NH_4)_2SO_4$, and $Ca(NO_3)_2$, and five parts of $MgSO_4$ plus Mn and Zn and the usual trace of iron turned out to be the best. This particular solution was used with success in subsequent experiments, and it proved that Mn and Zn are also good for the rice plants during the vegetative stage.

Influence of vitamin B_1

Vitamin B_1, commonly added to artificial culture media (Mitchell, 1940) was tried on rice in minute quantities. This vitamin B_1 is used as a root stimulant, "not for the initiation of root formation, but for the development of the roots", and that "any influence which vitamin B_1 may exert upon the growth of the shoot is primarily the result of its effect upon the root growth" (Shive, 1940).

In figure 1 the stands of the plants showed differences in response to the culture solutions employed (table 1). The differences in height and other yield data obtained, however, were mostly in favor of the cultures I, V, IX, and XIII, which did not receive any vitamin B_1. When Espino's 4-salt solution was tried (table 1, I-IV), the only significant difference was obtained from culture II, which received 0.1 milligram of vitamin B_1 per liter of the culture solution. This difference was in favor of the control. It appears that the application of vitamin B_1 to any of the four 4-salt solutions tried at the rates ranging from 0.01 to 0.1 milligram per liter of the culture solution failed to produce any significant increase of growth and development of the rice plants during the vegetative stage.

Influence of direct and diffused light

That rice when provided with water in the substratum can stand without harm the maximum intensity of the sun's illumination is borne by studies made by Espino and Pantaleon (1931). Table 2 and figure 2 show which of the two conditions of light, diffused or direct, would promote or prevent the formation of the "white tips" of rice. Table 2 and figure 2 also show the very apparent beneficial effects of direct illumination upon the state of development, heavy tillering, and the production of dark green leaves of the rice plants even though they were grown only in culture solutions.

When the yield data obtained (table 2) were compared (I with Ia, II with IIa, III with IIIa, and IV with IVa), marked differences were found not so much in height of plants and in length of roots, but in number of tillers and in dry matter. It was noted, however,

that "white tip" of rice also appeared in some cultures in diffused as well as in direct sunlight. Better growth and development of the plants during the vegetative stage were obtained from cultures exposed to direct sunlight, although the appearance of "white tip" was not altogether eliminated.

Effects of solution reaction

The importance of the reaction of culture solutions to rice was reported by several research workers, especially Jacobson (1925), Mitra and Phukan (1929), Gericke (1930), and Dastur and Winifred (1938). These workers employed culture solutions different from Espino's 4-salt type A. The findings of these workers led the writer to suspect that the failure of the rice plants during the vegetative stage to grow normally, without "white tip" and without dried leaves, might have been due, in part at least, to unfavorable pH values of Espino's 4-salt solution.

Changes in pH value of the solution were actually obtained (table 3) and although the rates of acidulation of similar nutrient solutions (cultures I to VII), which contained (by adjustment) different initial pH values, varied directly with the degree of the initial pH value, the actual result was that at the end of one week, the culture with a higher initial pH value became slightly less acidic than a similar solution with a lower initial pH value. For instance, culture I had an initial pH of 3.91, and at the end of one week, its reaction became pH 3.58. On the other hand, after one week the reaction of the solution in culture VII, which had an initial pH 7.04, became pH 3.90.

The experimental data in table 3 seem to show that varying the reactions of the solutions had no striking influence, one way or another, upon the height of the plants and on the length of roots. More tillers were, however, produced in the relatively less acidic than in the more acidic solutions. This behavior of the rice plants, in turn, was apparently largely responsible for the production of more dry weight of tops and of roots of the plants that were grown in the less acidic (pH 6.18 to 7.04 solutions).

In table 3 the differences of the test cultures from the control were practically all statistically insignificant. The control culture used was a new 4-salt solution with an initial reaction of pH 5.5. When the data for this solution were statistically compared with data obtained either from the more or from the less acidic solutions, the differences were all found to be insignificant. It appeared

very likely that the pH values ranging from pH 3.91 to 5.5 gave similar effects upon the rice plants. The pH values ranging from pH 5.5 to pH 7.04 gave also similar effects upon the plants.

The reactions of the cultures in the new 4-salt solution (table 3) were adjusted weekly to make them vary from pH 3.91 in I to pH 7.04 in VII, and to give the plants similar effects. In terms of dry weight of whole plants, the differences of the effects of the solution reactions between the pH 7.04, 6.52, or 6.18, on the one hand, and any of the pH values of pH 4.46 or lower, on the other, were all statistically significant. Moreover table 3 shows that all the solutions with pH values lower than 5.5, that is, pH 4.46 to pH 3.91, produced plants with certain physical injuries, brown roots and dried leaves at tips. It may, therefore, be concluded that the solution reactions indicated as pH 6.18, 6.52, and 7.04, particularly the last two, were beneficial to the rice plants during the vegetative stage. This result practically confirms Dastur and Winifred's (1938) findings. Using another culture solution, Gericke (1930) obtained the best results from rice in pH values ranging from 5.7 to 6.7.

In another set of solution cultures, the daily changes of the pH values of the culture solutions, with and without ferric phosphate, were determined with the use of the Student's potentiometer. The results given in table 7 showed that the addition of ferric phosphate ($FePO_4$. $2H_2O$) tended to make the 4-salt solution more acidic. In fact, the more iron and the more frequently ferric phosphate was added, even though little by little, the more rapid and acidic became the reaction.

On the other hand, the absence of iron in the culture solution brought about a much slower change of the pH values of the solution. This appears to be desirable in the nutrition of the rice plant or of most other green plants. Unfortunately, the lack of iron in the culture medium appeared to have produced rice plants with leaves that soon became extremely chlorotic (fig. 7).

In regard to the chlorosis in culture I, table 7 and figure 7 show that since cultures III, IV, and V which received $FePO_4$ were all green despite the relatively lower pH values, the chlorosis in culture can be attributed to lack of iron rather than to the acidity of the culture solution. Acidity of the culture media, in spite of the presence of iron, however, seemed to be somewhat responsible for making the leaves of the plants light green, for when the reaction of the solution was brought back to the original pH 5.5, in spite

of a very moderate application of the Fe-salt, the plants produced (culture II) not only appeared to be the healthiest in the set but their leaves were slightly broader and darker green than those of the other cultures.

Table 7 further shows that the original reaction of the new 4-salt solution used was around pH 5.5 and it always tended to become more acidic every day, at least when used for rice plants during the vegetative stage. The data also revealed that from the fourth to the seventh day, when the solution was renewed, further change of the reaction seldom occurred. On the fourth day, the solution had a pH value of about 3.85. In Jacobson's (1925) studies with rice, the change of reaction was from pH 5.0 before the plants were grown in the solution to an average of pH 3.0 after three days of growth in the same culture medium.

From the foregoing analyses of data, it was evident that the culture solution with a higher initial pH value became daily less acidic than a similar solution with a lower initial pH value. From the fourth day hardly any change in pH value took place. Fewer tillers and consequently less dry matter were produced in the more acidic solution.

It was also evident that an increase of acidity was brought about by a liberal addition of $FePO_4.2H_2O$ to the 4-salt solution. Although the absence or the presence of iron in insufficient amount was largely responsible for chlorosis, nevertheless, the low pH value of the solution perhaps also contributed to the production or intensification of the malady.

Influence of iron

Gines (1928) found that young rice plants could derive their supply of iron from a number of Fe-salts that he tested. He noted that addition of ferric phosphate ($FePO_4.2H_2O$) to Espino's 4-salt solution gave the plants during the seedling stage, good growth and development in terms of the amount of dry matter produced. In view of this good result, ferric phosphate was again employed in this study.

When added to 4-salt culture solutions at the rates ranging from 1 to 4 ml. per liter of culture solution (table 4), ferric phosphate seemed to have given the rice plants during the vegetative stage about the same effects. In dry weight of top, culture I (Espino's 4-salt solution) gave the lowest yield, but when statistically

compared with the yields from the other 4-salt solution, no significant difference was found. Thus, it can be said that the addition of iron to the new 4-salt solution at the rates ranging from 1 to 4 ml. per liter of the culture medium gave the plants no significant differences in the yield of top.

In the development of the roots, however, the addition of more ferric phosphate to the new 4-salt solution (table 4, cultures III to V) proved somewhat stimulating. Significant differences were obtained when comparison was made with culture I, Espino's 4-salt solution. It is, however, reasonable to suspect that such results strongly suggested that the beneficial effects were derived by the root not from Fe-ions but from the PO_4, which is known to stimulate growth and development of roots of plants in general. Moreover, when the dry matter of roots from cultures II to V were compared statistically with one another, no very significant differences were found. Therefore, the addition of $FePO_4$ to a new 4-salt solution, at the rates ranging from 1 to 4 ml., produced about the same effects upon the roots of rice plants during the vegetative stage.

When a study of the effects of iron upon rice plants during the vegetative stage was made (table 7 and fig. 7), it was again revealed that hardly any significant differences in dry matter or perhaps even in height between cultures were noted when ferric phosphate solution was applied at the rates ranging from 0 or 1 ml. to 6 ml. per liter of culture solution. This was particularly true to the requirement of the rice plants. But when the pH value of the solution was brought up to 6.5 every day, even one ml. of ferric phosphate per liter appeared to be sufficient. In culture II (table 7 and fig. 7*b*), the plants were very well developed and had rather dark green leaves. In terms of the dry weight of tops, only this culture showed a significant difference from the control, which received no additional supply of iron.

The plants in cultures III to V (table 7 and fig. 7) were also equally tall and fairly well-developed. And, with the exception of culture I, all cultures that received ferric phosphate, 1 to 6 ml. per liter of the solution each, produced broad, green leaves. Thus, it might appear that the addition of ferric phosphate to the 4-salt solution at the rates ranging from 1 to 6 ml. per liter of the culture solution, with or without adjustment of the pH value of the medium, produced fairly well-developed green rice plants during the vegetative stage. In fact, the use of a little more than 1 ml. (equivalent

to about 20 p.p.m.) of ferric phosphate per liter of the 4-salt solution used seemed to be sufficient. For rice plants during the seedling stage and when grown in Espino's 4-salt solution without trace elements, the best results were obtained from the application of ferric phosphate at the rate of 30 to 135 p.p.m. (Gines, 1928).

Drying of the older leaves at the base of the culms in cultures *a*, *d*, and *e* in figure 7 was noted. In table 7 where these cultures were labeled I, IV and V, respectively; the first received no additional supply of iron, whereas the other two received 3 and 6 ml. of the solution of ferric phosphate per liter of the culture medium. As may be seen in table 7, Fe-salts always tend to make a culture solution acidic by acting as a stimulant, promoting rapid absorption of the basic, and leaving behind the acid radicals. These changes might account for the drying of the leaves, although the induced rapid absorption of the basic ions might have also produced the drying. The presence of plants with similar dried leaves was noted in culture I which was a 4-salt culture solution without iron.

Whatever may be the cause of drying of the older leaves, the fact remains that, with cultures IV and V eliminated, owing to the physical injury, apparently initiated by the liberal application of iron, cultures II and III each of which received only 1 ml. (equivalent to 20 p.p.m.) of ferric phosphate solution per liter of culture solution with or without their pH values adjusted, produced very well-developed green plants without any physical injury.

An interesting feature of this particular experiment was the ability of the rice seedlings to continue growing and producing an appreciable amount of dry matter even though they were transferred to the 4-salt solution either without iron or with very little of it. As was expected, the plant during the vegetative stage turned very chlorotic. This result seemed to contradict Gericke's (1930) finding that "the absence of iron in the growth medium of young rice seedlings caused them to die prematurely". It should be pointed out, however, that Gericke did not renew the solution that he used in his experiment.

Effect of volume of solution

The nature and the rate of plant growth in culture solutions are influenced by various factors. One of these factors is the volume of the solution or size of the culture receptacle on the growth and development of plants. Figure 5 shows that the most vigorous growth of the plants in the 4-salt solution was produced in the

2.5-liter bottles, the largest tried in this study. In fact, the plants remained normal, that is, without signs of injury of any kind throughout the experiment. Moreover, the "white tip" of rice was never seen in these cultures, not even the drying of any of the leaves (fig. 5).

Table 5 shows that the different volumes of 4-salt culture solution tried produced different yields of dry matter. The average dry weights of tops and of roots produced were highest in the 2.5-liter cultures, and became progressively lower in the smaller solution volumes; the lowest yields were from the ¼-liter bottles. The production of tillers was also affected; more tillers were formed in the larger volumes than in the smaller volumes. The results seemed to confirm a similar study on wheat grown in modified Tottingham's solution containing among other salts, $(NH_4)_2SO_4$ (Barnette and Shive, 1923). These investigators found that the growth rates of wheat varied with the volume of the solution, the most vigorous growth by far being produced in the 2-liter cultures. They attributed the marked improvement of the growth and development of the plants when grown in bigger culture media to the presence in the solution of a more suitable hydrogen ion concentration.

Effects of salt proportions

Table 6 shows the salt proportions of the solutions used and the experimental data obtained when the main salts in the culture media were alternately varied. With the amounts of the other salts maintained constant, the amount of $MgSO_4$ was varied from 0.001 to 0.008 molar; that of $Ca(NO_3)_2$, from 0.0005 to 0.001 molar; that of $CaSO_4$, from 0.00375 to 0.001 molar; that of NH_4NO_3, from 0.001 to 0.002 molar; and that of KH_2PO_4, from 0.0005 to 0.001 molar. Both NH_4- and NO_3-ions were always simultaneously present in all the culture media.

The results showed that in spite of variation in the amounts of salts used, all the plants produced appeared tall and quite healthy. Even the yields of dry matter obtained from the different cultures were only slightly divergent so that when statistical comparisons were made no significant differences were found. The data on dry matter from culture I, the original Espino's 4-salt solution, were neither significantly better nor worse than those from any of the other cultures.

Like wheat (Gericke, 1928) and probably other plants, rice, at least during the vegetative stage, required for good growth and development a rather wide range of salt proportions.

A further study of the cultures was made and the results obtained (table 6 and fig. 6) showed that as the amount of a salt, or a growth factor, was increased or decreased, there was generally also a corresponding increase or decrease either in the number of tillers or in the amount of dry matter produced. This was expected since the growth and development of plants are governed by, and in accordance with, certain known "growth laws", which in this particular case happened to be the "law of diminishing increments of yield", the "concentration law", and the "law of joint action of growth factors" (Willcox, 1930). Although the increases or decreases (due to treatments), in what might for convenience be termed here as the "growth-yield", were little—so little perhaps that some were barely perceptible—nevertheless from the standpoint of the welfare of the plant, such changes of growth and development meant something.

Variations in the cultural treatments seemed to have also produced differences in the general appearance of the plants. As shown in figure 6, the culture media in table 6 produced rice plants with certain rather striking characteristics, which were perhaps influenced not so much by the varying salt proportions, but by the kind of salts or ions contained in the growth media. For instance, the plants that received NH_4NO_3 and $Ca(NO_3)_2$, in addition to the other constituents of the 4-salt solution, seemed to be the shortest because they were really so (table 6) and because their leaf tips looked crumpled or bent downward (fig. 6, *l* to *p*). On the other hand, the plants that looked stately, erect, and rather healthy received NH_4NO_3 and $CaSO_4$ in addition to the other salt contents of the 4-salt solution. Lastly, the plants which appeared intermediate between these two types received both $(NH_4)_2SO_4$ and $Ca(NO_3)_2$. Some of the leaves of these plants were rather erect, but several looked crumpled or bent downward.

On further study of the data in table 6, however, it finally appeared that these three striking and different characteristic stands of the plants were mainly due to the amount of nitrogen employed. The first group (fig. 6, *l* to *p*) received nitrogen from NH_4NO_3 and $Ca(NO_3)_2$ amounting to from 0.0015 to 0.0025 molar, (table 6, XII to XVI). The second group (fig. 6 *h* to *k*) received 0.000375 molar NH_4NO_3, (table 6 VIII to XI); and the third group (fig. 6, *a* to *g*)

received nitrogen from $(NH_4)_2SO_4$ and $Ca(NO_3)_2$ in amounts ranging from 0.00075 to 0.001375 molar (table 6, I to VII). Thus, it seemed quite probable that the differences in appearance of the plants were due to the different amounts of nitrogen employed. Evidently, such was really the case because the plants in the first group which received the greatest amount of nitrogen were dark green, indicating as usual an excess of nitrogen. The plants in the second group, that is, those that received the lowest amounts of nitrogen, were slightly pale green. And the plants in the third group had green leaves of just about the right intensity.

From the foregoing observations, it seemed clear that the contention that rice plants, like wheat (Gericke, 1928), can stand or rather require for good growth a rather wide range of salt proportions and total molecular concentrations is probably correct. But if the decision were to be based on excellent, perfect, or best growth, similar perhaps to that which Willcox (1930) would consider obtainable only from a "perfertile soil", then the range of salt proportions would not be so wide, as data from the present study revealed. And to claim as Gericke (1930) did "that the actual salt requirements of rice cannot be determined by growing plants to maturity in any so-called complete nutrient solution, however compounded", is, to say the least, probably a rather hasty generalization. For he himself was able to raise rice plants to maturity and produce grains in culture solutions; and there is no better index of the suitability of a culture solution to a plant than the kind of growth and development made in that medium.

An important thing revealed by the results of this study was that in determining the salt requirements of rice plants by the solution culture method, the data on dry matter were not always enough to give a true appraisal of the nutritive value of the solution. As brought out in the preceding discussion, the data on dry weight of the plant or any of its parts did not always reveal significant difference between the cultures that were being compared. Rice plants react in a variety of ways to the varied and varying conditions of their environment. For instance, when planted in soil of different degrees of fertility, they grew and even yielded grains but in different ways. Some became tall, others short. They produced leaves of different states of development and with varying intensity of the green color; and some cultures even showed physical injuries, such as the so-called "white tip" and drying of some leaves. The fact that rice seedlings receive physical

injuries when grown in certain culture solutions was kept in mind (Espino, 1920), and in the present study, the cultures were carefully observed not only for good qualities of the plants but also for physical injuries as well.

Variations in salt proportions and in total concentration, no matter how few they may be, usually produce differences in the reaction or response of the plants grown. And, in addition to the data already referred to (fig. 6), figure 1 may be presented as an additional evidence. In table 1, the plants shown in figure 1 received four different types of culture solutions. These solutions contained the same four main salts in Espino's 4-salt solution but they differed from one another by slight variations in salt proportions. The characteristic stands of the plants produced were distinctly different, apparently depending upon the salt proportions employed. For these reasons, it seems safe to say that contrary to the opinion of some workers, the study of the salt requirements of rice plant is possible, provided the criteria of results employed be mainly the best growth and at the same time the perfect development of the plants. Under these conditions, it can be said that the rice plants require a rather narrow range of salt proportions.

Effects of 3-salt and 4-salt solutions

The effects of 3-salt and of 4-salt solutions upon the growth and development of rice plants during the vegetative stage were observed (table 8 and fig. 8). Culture I was selected because it was found to be the most promising for rice in the series of cultures in connection with the studies on trace elements, the best in connection with vitamin B_1 (thiamin), and the best in diffused and direct sunlight. Moreover, this solution was repeatedly employed with success in connection with the studies on pH values, amount of iron, and volume of solution. It was compared with the original Espino's 4-salt solution (culture II), and the results showed that both cultures produced well-developed rice plants. In height and in yield of tops and of roots, however, culture I was decidedly better than culture II. In dry weight of the whole plant, culture I was 35.2 per cent better than culture II, the 4-salt solution found by Espino (1920) best for rice plants during the seedling stage. The latter solution contained, in addition to the usual trace of iron, the main salts KH_2PO_4, $(NH_4)_2SO_4$, $Ca(NO_3)_2$, and $MgSO_4$ but lacked trace elements. The main salts were present in the propor-

tion of 1:1½:1½:4 with a total concentration of 0.002 gram-molecule of all the salts taken together per liter.

On the other hand, culture I contained the main salts KH_2PO_4, $(NH_4)_2SO_4$, $Ca(NO_3)_2$, and $MgSO_4$ in the proportion of 1:1:1:5 with a total concentration also of 0.002 gram-molecule of all the salts taken together per liter. To this mixture were added $MnSO_4$ and $ZnSO_4$ at the rate of 10 p.p.m. each, and one ml. of 0.02 molar $Fe\ PO_4.2H_2O$ per liter of the culture medium, equivalent to about 20 p.p.m.

Comparisons were made between culture I and any of 3-salt solutions in table 8, and the results showed that in terms of dry weight of the whole plant, culture I, the best 4-salt solution so far found, was from 108 to 134.4 per cent better than cultures III, IV, and VI. Moreover, none of these cultures that had nitrogen only as NO_3 (without NH_4 or any NH_4-salt) produced normal green plants. Cultures III and IV, which received nitrogen only from $Ca(NO_3)_2$, produced rather stunted and chlorotic plants (fig. 8, *c* and *d*). Culture V, which was supplied with nitrogen from KNO_3 and $Ca(NO_3)_2$, produced rather tall plants but slightly chlorotic leaves (fig. 8, *e*). Culture VI, which received the three basic salts, KH_2PO_4, $Ca(NO_3)_2$, and $MgSO_4$ (without $(NH_4)_2SO_4$) failed to produce normally developed green rice plants. In fact, the plants that were not supplied with NH_4-nitrogen hardly grew from the seedling stage and were extremely chlorotic. Finally, of all the culture treatments given, nothing produced well-developed and perfectly green rice plants during the vegetative stage, except those that supplied the plants with NH_4 and NO_3-nitrogen, in addition to the other salt contents of the original Espino's 4-salt solution. Thus, it appeared that under the conditions of this study, rice plants during the vegetative stage required nitrogen both in the forms of NH_4 and NO_3 and that the plants not supplied with NH_4-nitrogen hardly grew from the seedling stage and they were extremely chlorotic.

Salt requirements during the seedling and vegetative stages

After the various salt proportions and several total molecular concentrations of the main salts, KH_2PO_4, $(NH_4)_2SO_4$, $Ca(NO_3)_2$, and $MgSO_4$ originally present in Espino's 4-salt solution were tried on rice during the vegetative stage, the best proportion was found to be 1:1:1:5 with a total concentration of 0.002 gram-molecule of all the salts taken together per liter, with or without adjust-

ment of pH value. To this mixture were added Mn and Zn and the usual trace of iron. For the seedling stage, Espino (1920) obtained the best growth and development from a mixture or mixtures of the same four salts and with the same total concentration, with the usual trace of iron but without any trace element, and also without adjustment of the pH value of the growth medium. This latter solution has been called Espino's 4-salt solution type A to distinguish it from another 4-salt solution (without $(NH_4)_2SO_4$) which Espino had also used.

When these two solutions were simultaneously tried on rice plants during the vegetative stage, it was found that the new solution was far superior to the other. And, when Espino's 4-salt proportion 1:1½:1½:4 was compared with itself plus trace elements, the latter was found better. Finally, when the new 4-salt solution with trace elements was compared with Espino's 4-salt solution, with or without trace elements, the new 4-salt solution always excelled the latter.

It thus appeared that the rice plants seemed to require for best growth and development one salt proportion for the seedling stage, and another salt proportion for the vegetative stage.

On careful perusal of Espino's (1920) paper, however, it was discovered that for excellent growth of rice seedlings, he obtained three salt proportions, one of which was 1:1:1:5 with a total concentration of 0.002 gram-molecule of all the salts taken together per liter. This being also the proportion found best in the present study, therefore, the proportion of the main four salts best for the seedling stage was also the best for the vegetative stage, with just one difference-that trace elements were tried and found beneficial for the vegetative stage but had not yet been tried for the seedling stage. It should be said that the solution designated as Espino's 4-salt solution with the salt proportion 1:1½:1½:4 is the average of the three most promising salt proportions found in 1920 which after repeated trials was finally found also most promising for rice seedlings.

From the foregoing discussion, it seems quite probable that the salt requirements of rice plants during the vegetative stage is similar to the salt requirement during the seedling stage, with apparently great difference in solution volume requirement and especially in the reaction of the solution. The vegetative stage appears to be much more sensitive or more exacting in these cultural requirements than the seedling stage. This difference is in most prob-

ability due to the difference in the rate of absorption of certain ions—faster during the vegetative stage than during the seedling stage. An analysis of the culture media should be made to verify this assertion.

SUMMARY

1. The addition of Mn and B at certain concentrations to Espino's 4-salt solution improved the growth and development of rice plants during vegetative stage. The combination of Mn and B when added to certain 4-salt solutions also proved beneficial to the plants. Subsequent trials of solution cultures showed that Mn + Zn was also good for rice during the vegetative stage.

2. The "white tip" of rice is not due either to the absence or to the presence of trace elements in the culture media.

3. The application of vitamin B_1 to any of the four 4-salt solutions tried, at the rates ranging from 0.01 to 0.1 mgs. per liter of the culture solution, failed to produce any significant increase of growth and development during the vegetative stage over the culture not supplied with vitamin B_1.

4. Better growth and development of the plant during the vegetative stage were obtained by exposing the cultures to direct sunlight. However, the appearance of "white tip" was not altogether eliminated.

5. Varying the reaction of the culture solution from pH 3.91 to pH 7.04 had no influence upon the height of the plants and upon the length of the roots. More tillers were, however, produced in the less acidic than in the more acidic solutions.

6. The 4-salt solution with the reaction ranging from pH 5.91 to pH 4.46 produced rice plants with certain physical injuries, brown roots and leaves dried at the tips. But pH values 6.18, 6.52, and 7.04, particularly the last two, were beneficial to the rice plants during the vegetative stage.

7. An increase of acidity was brought about by a liberal addition of $FePO_4.2H_2O$ to the 4-salt solution. Although the absence of iron or its presence in insufficient amount was largely responsible for the chlorosis observed, nevertheless, low pH value of the solution perhaps also contributed in producing or in intensifying the malady.

8. Addition of iron to a new 4-salt solution at the rate ranging from 1 to 4 ml. per liter of the culture medium produced about the same effects upon rice plants during the vegetative stage. But

addition of a little more than 1 ml. of 0.02 molar (equivalent to about 20 p.p.m.) ferric phosphate per liter of the 4-salt solution, with or without adjustment of pH value, seemed to be sufficient.

9. Drying of the older leaves of the rice plants when grown in 4-salt solution supplied with 3 and 6 ml. of 0.02 molar solution of ferric phosphate per liter of the culture medium was observed. The real cause of the drying, however, was not ascertained in this study.

10. The absence of iron in the 4-salt solution produced tall and very chlorotic rice plants during the vegetative stage.

11. The most vigorous growth and the production of the greatest number of tillers were obtained from rice plants during the vegetative stage when they were supplied with 2.5 liters of the 4-salt solution, the largest amount tried in this study.

12. Under the conditions of this study, rice plants during the vegetative stage required nitrogen both in the forms of NH_4 and NO_3. The plants which were not supplied with NH_4-nitrogen hardly grew beyond the seedling stage and they were extremely chlorotic.

13. Contrary to the opinion of some workers, the study of the salt requirements of the rice plant is possible provided the criteria of results employed are principally the best growth and development of the plant. Under these conditions, it can be said that rice plants required a rather narrow range of salt proportions.

14. It seems quite probable that the salt requirements of rice plants during the vegetative stage is similar to the salt requirements during the seedling stage. Apparently the difference lies in volume of the solution required and in reaction of the solution. The vegetative stage of rice appears to be much more exacting in its cultural requirements than the seedling stage. This difference, as suggested by literature, is most probably due to the difference in the rate of absorption of certain ions. The faster absorption by rice during the vegetative stage than during the seedling stage finally makes the remaining culture medium more or less toxic to the plant. Analysis of the culture media should be made to verify this assertion.

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TABLE 1

Effects upon growth and development of lowland rice plants during the vegetative stage of adding vitamin B_1 to four 4-salt solutions (Experiment from September 19 to October 31, 1940; data are averages of triplicate cultures)

CULTURE NO.	SALT PROPORTIONS				TRACE ELEMENTS	VITAMIN B_1	HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	APPEARANCE OF PLANTS AT HARVEST
	KH_2PO_4	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$MgSO_4$		*mg./l.*				
	moles	*moles*	*moles*	*moles*	0		*cm.*	*cm.*		
I	0.00025	0.000375	0.000375	0.001	(control)	0	65.0	17.7	4.3	
II	0.00025	0.000375	0.000375	0.001	0	0.1	62.2	15.3	3.0	
III	0.00025	0.000375	0.000375	0.001	0	0.05	67.6	17.8	4.3	
IV	0.00025	0.000375	0.000375	0.001	0	0.01	72.2	16.5	3.0	
					10 pp.m. aa.					
V	0.00025	0.00025	0.00025	0.00125	Mn. Zn	0	78.5	26.5	3.0	All cultures were green; V to VIII were more vigorous than the rest; and IX to XI, slightly darker green. Cultures I to IV appeared quite similar from cultures XIII to XVI, with rather crumpled, slightly pale green leaves.
VI	0.00025	0.00025	0.00025	0.00125	Mn. Zn	0.1	75.3	28.5	4.5	
VII	0.00025	0.00025	0.00025	0.00125	Mn. Zn	0.05	76.1	25.3	3.0	
VIII	0 00025	0.00025	0.00025	0.00125	Mn. Zn	0.01	73.2	22.9	3.7	
IX	0.00025	0.00025	0.0005	0.001	Mn. B	0	72.8	17.8	5.0	
X	0.00025	0.00025	0.0005	0.001	Mn. B	0.1	71.1	16.2	3.0	
XI	0.00025	0.00025	0.0005	0.001	Mn. B	0.05	70.6	17.2	4.3	
XII	0.00025	0.00025	0.0005	0.001	Mn. B	0.01	71.2	18.2	4.7	
XIII	0.00025	0.000375	0.000375	0.001	Mn. Cu	0	74.2	25.8	2.5	
XIV	0.00025	0.000375	0.000375	0.001	Mn. Cu	0.1	70.0	23.8	3.0	
XV	0.00025	0.000375	0.000375	0.001	Mn. Cu	0.05	68.8	21.8	4.7	
XVI	0.00025	0.000375	0.000375	0.001	Mn. Cu	0.01	70.2	25.0	3.7	

TABLE 1—(Continued)

Effects upon growth and development of lowland rice plants during the vegetative stage of adding vitamin B_1 to four 4-salt solutions (Experiment from September 19 to October 31, 1940; data are averages of triplicate cultures)

CULTURE NO.	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	STATISTICAL DIFFERENCE FROM CONTROL			APPEARANCE OF PLANTS AT HARVEST
				Dry weight of top	Dry weight of root	Dry weight of whole plant	
	grams	*grams*	*grams*	*gram*	*gram*	*gram*	
I	2.01 ∓ 0.17	0.38 ∓ 0.03	2.39 ∓ 0.13				
II	1.62 ∓ 0.07	0.30 ∓ 0.03	1.92 ∓ 0.12	—0.39 ∓ 0.18 sig.	—0.08 ∓ 0.04 sig.	—0.47 ∓ 0.18 sig.	
III	2.17 ∓ 0.14	0.39 ∓ 0.03	2.56 ∓ 0.15	0.16 ∓ 0.22 insig.	0.01 ∓ 0.04 insig.	0.17 ∓ 0.20 insig.	
IV	2.11 ∓ 0.63	0.38 ∓ 0.01	2.49 ∓ 0.02	0.10 ∓ 0.17 insig.	0.00 ∓ 0.03 insig.	0.10 ∓ 0.13 insig.	
V	2.42 ∓ 0.09	0.79 ∓ 0.10	3.21 ∓ 0.19	0.41 ∓ 0.19 sig.	0.41 ∓ 0.10 sig.	0.82 ∓ 0.23 sig.	All cultures were green; V to VIII were more vigorous than the rest, and IX to XI slightly darker green. Cultures I to IV appeared quite similar to from cultures XIII to XVI, with rather crumpled, slightly pale green leaves.
VI	2.57 ∓ 0.16	0.72 ∓ 0.04	3.29 ∓ 0.20	0.56 ∓ 0.23 sig.	0.34 ∓ 0.05 sig.	0.90 ∓ 0.24 sig.	
VII	2.49 ∓ 0.04	0.69 ∓ 0.06	3.18 ∓ 0.10	0.48 ∓ 0.17 sig.	0.31 ∓ 0.07 insig.	0.79 ∓ 0.16 sig.	
VIII	2.35 ∓ 0.08	0.64 ∓ 0.06	2.99 ∓ 0.22	0.34 ∓ 0.19 insig.	0.26 ∓ 0.07 sig.	0.60 ∓ 0.26 sig.	
IX	2.53 ∓ 0.07	0.55 ∓ 0.03	3.08 ∓ 0.06	0.52 ∓ 0.18 sig.	0.17 ∓ 0.04 sig.	0.69 ∓ 0.14 sig.	
X	2.58 ∓ 0.14	0.54 ∓ 0.05	2.92 ∓ 0.20	0.37 ∓ 0.22 insig.	0.16 ∓ 0.06 sig.	0.53 ∓ 0.24 sig.	
XI	2.09 ∓ 0.16	0.40 ∓ 0.03	2.49 ∓ 0.17	0.08 ∓ 0.23 insig.	0.02 ∓ 0.04 insig.	0.10 ∓ 0.21 insig.	
XII	2.15 ∓ 0.11	0.49 ∓ 0.02	2.64 ∓ 0.10	0.14 ∓ 0.20 insig.	0.11 ∓ 0.04 sig.	0.25 ∓ 0.16 insig.	
XIII	2.19 ∓ 0.35	0.48 ∓ 0.06	2.67 ∓ 0.41	0.18 ∓ 0.39 insig.	0.10 ∓ 0.07 insig.	0.28 ∓ 0.43 insig.	
XIV	2.38 ∓ 0.14	0.52 ∓ 0.07	2.90 ∓ 0.17	0.37 ∓ 0.22 insig.	0.14 ∓ 0.08 insig.	0.51 ∓ 0.21 sig.	
XV	2.35 ∓ 0.14	0.59 ∓ 0.11	2.94 ∓ 0.25	0.34 ∓ 0.22 insig.	0.21 ∓ 0.11 insig.	0.55 ∓ 0.28 insig.	
XVI	2.14 ∓ 0.20	0.55 ∓ 0.03	2.69 ∓ 0.23	0.13 ∓ 0.26 insig.	0.17 ∓ 0.04 sig.	0.30 ∓ 0.26 insig.	

TABLE 2

Effects of direct or diffused sunlight upon growth and development of lowland rice plants during the vegetative stage and when grown in 4-salt solutions
(Experiment from September 19 to October 30, 1940; data are averages of triplicate cultures)

(a) Diffused light

CULTURE NO.	SALT PROPORTIONS				TRACE ELEMENTS	HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	APPEARANCE OF PLANTS AT HARVEST
	KH_2PO_4	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$MgSO_4$					
	moles	*moles*	*moles*	*moles*		*cm.*	*cm.*		
I	0.00025	0.000375	0.000375	0.001	control (0)	54.2	16.7	0	Culms, slender; leaves, narrow and slightly less green; roots, a little brown and very poorly developed.
II	0.00025	0.00025	0.00025	0.00125	10 p.p.m. ea. Mn. + Zn	63.2	19.5	0	
III	0.00025	0.00025	0.0005	0.0010	Mn. + B	60.5	22.4	0	
IV	0.00025	0.000375	0.000375	0.001	Mn. + Cu	63.9	21.6	0	

(b) Direct light

I a	0.00025	0.000375	0.000375	0.001	0 (control)	70.2	22.6	4.7	All cultures very well developed, with dark green and broad leaves. Much more vigorous than those in cultures I to IV.
II a	0.00025	0.00025	0.00025	0.00125	10 p.p.m. ea. Mn. Zn	67.2	30.2	6.0	
III a	0.00025	0.00025	0.0005	0.001	Mn. B	66.9	24.1	5.3	
IV a	0.00025	0.000375	0.000375	0.001	Mn. Cu	67.6	25.1	5.0	

TABLE 2 (continued)

(*a*) *Diffused light*

CULTURE NO.	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	STATISTICAL DIFFERENCES FROM CONTROL			APPEARANCE OF PLANTS AT HARVEST
				Dry weight of top	Dry weight of root	Dry weight of whole plant	
	grams	*gram*	*grams*	*gram*	*gram*	*gram*	
I	0.42 ∓ 0.11	0.07 ∓ 0.02	0.49 ∓ 0.12				Culms, slender; leaves, narrow and slightly less green; roots a little brown and very poorly developed.
II	0.78 ∓ 0.03	0.12 ∓ 0.01	0.90 ∓ 0.03	0 36 ∓ 0.11 sig.	0.05 ∓ 0.02 sig.	0.41 ∓ 0.12 sig.	
III	0.66 ∓ 0.05	0.11 ∓ 0.01	0.77 ∓ 0.05	0.24 ∓ 0.12 sig.	0.04 ∓ 0.02 sig.	0.28 ∓ 0.13 sig.	
IV	0.76 ∓ 0.11	0.13 ∓ 0.02	0.89 ∓ 0.12	0.34 ∓ 0.15 sig.	00.06 ∓ 0.03 sig.	0.40 ∓ 0.17 sig.	

(*b*) *Direct light*

I a	2.24 ∓ 0.08	0.49 ∓ 0.04	2.73 ∓ 0.12				All cultures very well developed, with dark green and broad leaves. Much more vigorous than those in cultures I to IV.
II a	2.48 ∓ 0.27	0.74 ∓ 0.17	3.22 ∓ 0.44	0.24 ∓ 0.28 insig.	0.25 ∓ 0.18 insig.	0.49 ∓ 0.46 insig.	
III a	2.50 ∓ 0.12	0.58 ∓ 0.04	3.08 ∓ 0.16	0.26 ∓ 0.14 insig.	0.09 ∓ 0 06 insig.	0.35 ∓ 0.20 insig.	
IV a	2.02 ∓ 0.29	0.44 ∓ 0.04	2.46 ∓ 0.21	—0.22 ∓ 0.30 insig.	—0.05 ∓ 0.06 insig.	—0.27 ∓ 0.24 insig.	

TABLE 3

Effects upon growth and development of lowland rice plants during the vegetative stage of adjusting the reaction of the new 4-salt solution [a]

(Experiment from September 19 to October 31, 1940; data are averages of triplicate cultures)

CULTURE NO.	pH CONCENTRATION OF CULTURE SOLUTION		HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	EXTERNAL APPEARANCE OF PLANTS AT HARVEST
	Before using	One week later							
			cm.	*cm.*		*grams*	*grams*	*grams*	
I	3.91	3.58	65.4	22.5	3.3	1.96 ∓ 0.21	0.45 ∓ 0.04	2.41 ∓ 0.25	Leaves, green; roots, brown
II	4.12	3.58	64.5	18.5	4.7	2.02 ∓ 0.13	0.45 ∓ 0.02	2.47 ∓ 0.15	Leaves, green with a few dried leaf tips, roots unhealthy
III	4.46	3.64	63.8	21.1	4.0	2.11 ∓ 0.13	0.51 ∓ 0.05	2.62 ∓ 0.17	Same as culture II
IV	5.50	3.68	65.5	23.5	5.7	2.44 ∓ 0.20	0.67 ∓ 0.09	3.11 ∓ 0.29	Leaves, green; roots fairly well-developed
V	6.18	3.75	71.6	24.3	6.0	2.74 ∓ 0.23	0.67 ∓ 0.07	3.41 ∓ 0.30	Plants, well-developed; roots, healthy
VI	6.52	3.84	64.9	22.7	6.3	2.85 ∓ 0.18	0.73 ∓ 0.05	3.58 ∓ 0.21	Plants, well-developed; roots, healthy
VII	7.04	3.90	62.9	23.7	5.7	2.88 ∓ 0.21	0.89 ∓ 0.03	3.77 ∓ 0.24	Plants, well-developed; roots, healthy

[a] The pH values are averages and were differently adjusted by addition of HCl or NaOH to culture solution. The pH value (5.5) in culture IV (control) was obtained without adjustment, being the original reaction of the culture solution. The new best 4-salt solution contained 0.00025 M each KH_2PO_4, $(NH_4)_2SO_4$ and $Ca(NO_3)_2$ and 0.00125 M $MgSO_4$ with total molar concentration of 0.002 (of all the salts taken together) per liter. Manganese and zinc were added at the rate of 10 p.p.m.

TABLE 3 (continued)

CULTURE NO.	STATISTICAL DIFFERENCE OF CONTROL			EXTERNAL APPEARANCE OF PLANTS AT HARVEST
	Dry weight of top	Dry weight of root	Dry weight of whole plant	
	gram	*gram*	*gram*	
I	—0.48 ∓ 0.29 insig.	—0.22 ∓ 0.10 sig.	—0.70 ∓ 0.38 insig.	Leaves, green; roots, brown
II	—0.42 ∓ 0.24 insig.	—0.22 ∓ 0.09 sig.	—0.64 ∓ 0.33 insig.	Leaves, green with a few dried leaf tips; roots, unhealthy
III	—0.33 ∓ 0.24 insig.	—0.16 ∓ 0.10 insig.	—0.49 ∓ 0.34 insig.	Same as culture II
IV [a]				Leaves, green; roots, fairly well-developed
V	+0.30 ∓ 0.31 insig.	0.00 ∓ 0.11 insig.	0.30 ∓ 0.42 insig.	Plants, well-developed; roots, healthy
VI	+0.41 ∓ 0.27 insig.	0.06 ∓ 0.10 insig.	0.47 ∓ 0.36 insig.	Plants, well-developed; roots, healthy
VII	+0.44 ∓ 0.29 insig.	0.22 ∓ 0.10 sig.	0.66 ∓ 0.38 insig.	Plants, well-developed; roots, healthy

[a] Employed as basis for statistical comparison.

TABLE 4

Effects upon growth and development of lowland rice plants during the vegetative stage of adding $FePO_4$ in varying amounts to the new 4-salt solution [a]

(Experiment from September 19 to October 31, 1940, data are averages of triplicate cultures)

CULTURE NO.	AMOUNT OF $FePO_4$ ADDED	HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	EXTERNAL APPEARANCE OF PLANTS AT HARVEST
		cm.	*cm.*		*grams*	*grams*	*grams*	
I	1 c.c.	69.7	25.9	6.0	3.39 ∓ 0.29	0.68 ∓ 0.05	4.07 ∓ 0.34	Leaves, green; a few dried leaf tips; roots, slightly brown
II	1 c.c.	67.2	26.9	6.7	3.41 ∓ 0.30	0.85 ∓ 0.10	4.26 ∓ 0.39	Leaves, green; youngest leaf, light green; roots, slightly brown
III	2 c.c.	69.9	32.7	7.3	3.96 ∓ 0.11	1.16 ∓ 0.15	5.12 ∓ 0.23	Plants, green; roots, healthy
IV	3 c.c.	73.7	34.8	6.3	3.92 ∓ 0.16	1.11 ∓ 0.04	5.03 ∓ 0.18	Leaves, dark green; a few dried leaves; roots, healthy
V	4 c.c.	71.9	34.9	7.7	3.91 ∓ 0.19	1.03 ∓ 0.05	4.94 ∓ 0.10	Leaves, dark green; a few dried leaves; roots, healthy

[a] Culture I—Espino's 4-salt solution type A.

Culture II-V the new best 4-salt solution contained 0.00025 M KH_2PO_4; 0.00025 M $(NH_4)_2SO_4$, 0.00025 M $Ca(NO_3)_2$, and 0.00125 M $MgSO_4$ with a total concentration of 0.002 gram-molecule (of all the salts taken together) per liter. Manganese and zinc were each added at the rate of 10 p.p.m.

TABLE 4 (continued)

CULTURE NO.	STATISTICAL DIFFERENCES FROM CONTROL			EXTERNAL APPEARANCE OF PLANTS AT HARVEST
	Dry weight of top	Dry weight of root	Dry weight of whole plant	
I				Leaves, green; a few dried leaf tips; roots, slightly brown
II	0.02 ∓ 0.42 insig.	0.17 ∓ 0.11 insig.	0.19 ∓ 0.52 insig.	Leaves, green; youngest leaf, light green; roots, slightly brown
III	0.57 ∓ 0.31 insig.	0.48 ∓ 0.16 sig.	1.05 ∓ 0.41 sig.	Plants, green; roots, healthy
IV	0.53 ∓ 0.33 insig.	0.43 ∓ 0.06 sig.	0.96 ∓ 0.38 sig.	Leaves, dark green; a few dried leaves; roots healthy
V	0.52 ∓ 0.35 insig.	0.35 ∓ 0.07 sig.	0.87 ∓ 0.39 sig.	Leaves, dark green; a few dried leaves; roots, healthy

TABLE 5

Effects of size of bottles upon the growth and development of lowland rice during vegetative stage grown in the new 4-salt solution [a]

(Experiment from September 19 to October 31, 1940; data are averages of triplicate cultures)

CULTURE NO.	SIZE OF BOTTLES	HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	APPEARANCE OF PLANTS AT HARVEST
		cm.	*cm.*		*grams.*	*grams.*	*grams.*	
I	250 cc.	68.5	26.6	9.0	5.43 ∓ 0.39	1.37 ∓ 0.18	6.80 ∓ 0.01	Plants, very well-developed; bushy green, shoots
II	1000 cc.	66.9	24.9	5.7	2.61 ∓ 0.07	0.67 ∓ 0.06	3.28 ∓ 0.16	Plants, fairly well-developed and green
III	750 cc.	63.8	26.9	5.7	2.35 ∓ 0.17	0.69 ∓ 0.09	3.04 ∓ 0.27	Plants, green; youngest leaf, light green
IV	250 cc.	60.4	24.8	1.7	1.20 ∓ 0.08	0.50 ∓ 0.05	1.70 ∓ 0.13	Plants, green; culms slender; youngest leaf, whitish green

[a] The new best4-salt solution contained 0.05025 M ....., 0.00025 M $(NH_4)_2SO_4$, 0.00025 M $Ca(NO_3)_2$, and 0.00125 M $MgSO_4$ with a total molar concentration of 0.002 (of all the salts taken together) per liter. Manganese and zinc were each added at the rate of 10 p.p.m.

TABLE 5—(Continued)

CULTURE NO.	STATISTICAL DIFFERENCES FROM CONTROL			APPEARANCE OF PLANTS AT HARVEST
	Dry weight of top	Dry weight of root	Dry weight of whole plant	
	grams	*gram*	*grams*	
I				Plants, very well-developed; bushy green, shoots
II	—2.82 ∓ 0.40 sig.	—0.70 ∓ 0.19 sig.	—3.52 ∓ 0.16 sig.	Plants, fairly well-developed and green
III	—3.08 ∓ 0.43 sig.	—0.68 ∓ 0.20 sig.	—3.76 ∓ 0.27 sig.	Plants, green; youngest leaf, light green
IV	—4.23 ∓ 0.40 sig.	—0.87 ∓ 0.19 sig.	—5.10 ∓ 0.13 sig.	Plants, green; culms, slender; youngest leaf, whitish green

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TABLE 6

Lowland rice plants in the vegetative stage grown in complete culture solutions containing salts in different proportions with different total molar concentrations
(Experiment from September 19 to October 31, 1940; data are averages of triplicate cultures)

CULTURE NO.	SALT PROPORTIONS						TOTAL MOLAR CONCENTRATION	HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	APPEARANCE OF PLANTS AT HARVEST
	KH_2PO_4	$(NH_4)_2SO_4$	NH_4NO_3	$Ca(NO_3)_2$	$CaSO_4$	$MgSO_4$					
	moles	*moles*	*moles*	*moles*	*moles*	*moles*		*cm.*	*cm.*		
I	0.00025	0.000375	—	0.000375	—	0.001	0.002	70.1	21.5	4.7	Leaves, green; many dried leaf tips; youngest furled leaf, pale white
II	0.00025	0.000375	—	0.000375	—	0.002	0.003	70.4	18.1	4.3	Plants, vigorous, green but some leaves erect; other leaves, bent downward
III	0.00025	0.000375	—	0.000375	—	0.004	0.005	75.8	22.0	5.0	
IV	0.00025	0.000375	—	0.000375	—	0.008	0.009	74.3	20.0	6.0	
V	0.00025	0.000375	—	0.0005	—	0.001	0.002125	70.5	21.0	4.0	
VI	0.00025	0.000375	—	0.00075	—	0.001	0.002375	72.8	21.2	5.7	
VII	0.00025	0.00037	—	0.001	—	0.001	0.002625	75.0	18.9	7.0	Plants, stately erect, not so green as compared with the others
VIII	0.00025	—	0.000375	—	0.000375	0.001	0.002	75.4	29.3	3.7	
IX	0.00025	—	0.000375	—	0.0005	0.001	0.002125	75.6	28.3	4.3	
X	0.00025	—	0.000375	—	0.00075	0.001	0.002375	72.6	33.8	4.3	
XI	0.00025	—	0.000375	—	0.001	0.001	0.002625	71.4	29.6	4.3	
XII	0.00025	—	0.001	0.0005	—	0.001	0.00275	66.2	20.1	5.7	Plants with dark green rather crumpled leaves. Culture XVI with leaves, light green; and several old leaves, dry
XIII	0.00025	—	0.0015	0.0005	—	0.001	0.00325	71.2	16.3	5.3	
XIV	0.00025	—	0.002	0.0005	—	0.001	0.00375	69.8	18.8	4.0	
XV	0.0005	—	0.001	0.0005	—	0.001	0.003	69.9	19.2	5.3	
XVI	0.001	—	0.001	0.0005	—	0.001	0.0035	65.4	19.9	7.7	

TABLE 6 (continued)

CULTURE NO.	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	STATISTICAL DIFFERENCES FROM CONTROL			APPEARANCES OF PLANTS AT HARVEST
				Dry weight of top	Dry weight of root	Dry weight of whole plant	
	grams	*gram*	*grams*	*gram*	*gram*	*gram*	
I	2.50 ∓ 0.30	0.55 ∓ 0.08	3.05 ∓ 0.38				Leaves, green; many dried leaf tips; youngest furled leaf, pale white
II	2.31 ∓ 0.04	0.47 ∓ 0.02	2.78 ∓ 0.05	—0.19 ∓ 0.30 insig.	—0.08 ∓ 0.08 insig.	—0.27 ∓ 0.38 insig.	Plants, vigorous, green; but some leaves, erect; other leaves, bent downward
III	2.79 ∓ 0.04	0.53 ∓ 0.02	3.32 ∓ 0.04	0.29 ∓ 0.30 insig.	—0.02 ∓ 0.08 insig.	0.27 ∓ 0.38 insig.	
IV	3.09 ∓ 0.79	0.73 ∓ 0.12	3.82 ∓ 0.94	0.59 ∓ 0.85 insig.	0.18 ∓ 0.14 insig.	0.77 ∓ 1.01 insig.	
V	2.39 ∓ 0.11	0.49 ∓ 0.0[illegible]	2.88 ∓ 0.17	0.11 ∓ 0.32 insig.	—0.06 ∓ 0.10 insig.	—0.17 ∓ 0.42 insig.	
VI	2.59 ∓ 0.19	0.49 ∓ 0.03	3.08 ∓ 0.20	0.09 ∓ 0.36 insig.	—0.08 ∓ 0.09 insig.	0.03 ∓ 0.43 insig.	
VII	2.56 ∓ 0.18	0.46 ∓ 0.02	3.02 ∓ 0.22	0.06 ∓ 0.35 insig.	—0.09 ∓ 0.08 insig.	—0.03 ∓ 0.44 insig.	Plants, stately erect, not so green as compared with the others.
VIII	2.03 ∓0.09	0.58 ∓ 0.06	2.61 ∓ 0.14	—0.47 ∓ 0.31 insig.	0.03 ∓ 0.10 insig.	—0.44 ∓ 0.41 insig.	
IX	2.14 ∓ 0.08	0.55 ∓ 0.08	2.69 ∓ 0.15	—0.38 ∓ 0.31 insig.	0.00 ∓ 0.11 insig.	0.36 ∓ 0.41 insig.	
X	2.34 ∓ 0.02	0.68 ∓ 0.03	3.02 ∓ 0.04	—0.16 ∓ 0.30 insig.	0.13 ∓ 0.09 insig.	—0.03 ∓ 0.38 insig.	
XI	2.74 ∓ 0.06	0.92 ∓ 0.04	3.66 ∓ 0.10	0.24 ∓ 0.31 insig.	0.37 ∓ 0.09 sig.	0.61 ∓ 0.39 insig.	
XII	2.89 ∓ 0.27	0.59 ∓ 0.05	3.48 ∓ 0.32	0.30 ∓ 0.40 insig.	0.04 ∓ 0.09 insig.	0.43 ∓ 0.50 insig.	Plants with dark green rather crumpled leaves. Culture XVI with leaves, light green and several old leaves dry
XIII	2.42 ∓ 0.20	0.48 ∓ 0.01	2.90 ∓ 0.21	—0.08 ∓ 0.36 insig.	0.07 ∓ 0.08 insig.	—0.15 ∓ 0.43 insig.	
XIV	2.61 ∓ 0.65	0.44 ∓ 0.01	3.05 ∓ 0.21	0.11 ∓ 0.72 insig.	0.11 ∓ 0.08 insig.	0.00 ∓ 0.43 insig.	
XV	2.59 ∓ 0.11	0.52 ∓ 0.03	3.11 ∓ 0.11	0.09 ∓ 0.32 insig.	0.03 ∓ 0.09 insig.	0.06 ∓ 0.40 insig.	
XVI	2.84 ∓ 0.03	0.57 ∓ 0.02	3.41 ∓ 0.01	0.34 ∓ 0.30 insig.	0.02 ∓ 0.08 insig.	0.36 ∓ 0.38 insig.	

TABLE 7

Lowland rice plants in the vegetative stage grown in the new best 4-salt solution with amount of $FePO_4$ added at different times [a]
(Experiment from October 20 to November 18, 1940; data are averages of triplicate cultures)

CULTURE NO.	DAILY CHANGES IN HYDROGEN ION CONCENTRATION [b]							AMOUNT OF $FePO_4$ ADDED PER WEEK	HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	APPEARANCE OF PLANTS AT HARVEST
	1st	2nd	3rd	4th	5th	6th	7th					
	pH	*pH*	*pH*	*pH*	*pH*	*pH*	*pH*		*cm.*	*cm.*		
I	5.15	4.05	4.00	4.00	4.00	4.00	4.00	No iron per liter	62.4	24.1	8.5	Leaves, chlorotic; culms, soft; youngest, furled leaf, white
II	6.50	5.50-6.5	5.10-6.5	5.15-6.5	5.70-6.5	6.80-6.5	6.0-6.5	1 cc.	65.8	25.1	7.7	Plants, healthy, with broad green leaves; roots healthy
III	5.50	4.60	4.45	3.85	3.85	3.85	3.85	1 cc.	65.9	25.8	9.7	Plants, fairly well-developed
IV	5.50	4.60	4.30	3.95	3.85	3.85	3.85	3 cc.	58.7	26.1	8.5	Leaves, green; older leaves, dry
V	5.50	4.55	4.25	3.83	3.75	3.75	3.75	6 cc.	69.1	26.1	7.0	Leaves, green; older leaves and leaf tips dry

[a] The new best 4-salt solution contained 0.00025 M KH_2PO_4, 0.00025 M $(NH_4)_2SO_4$, 0.00025 M $Ca(NO_3)_2$, and $MgSO_4$ with a total molar concentration of 0.002 (of all the salts taken together) per liter. Manganese and zinc were each added at the rate of 10 p.p.m.

[b] The pH concentration of culture II was brought back to 6.5 every day by adding NaOH.

TABLE 7 (continued)

CULTURE NO.	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	STATISTICAL DIFFERENCE FROM CONTROL			APPEARANCE OF PLANTS AT HARVEST
				Dry weight of top	Dry weight of root	Dry weight of whole plant	
	grams	*grams*	*grams*				
I	4.09 ∓ 0.06	0.92 ∓ 0.03	5.01 ∓ 0.08				Leaves, chlorotic; culms, soft; youngest, furled leaf white
II	4.32 ∓ 0.06	0.94 ∓ 0.07	5.26 ∓ 0.12	0.23 ∓ 0.09 sig.	0.02 ∓ 0.08 insig.	0.25 ∓ 0.14 insig.	Plants, healthy, with broad green leaves; roots healthy
III	4.18 ∓ 0.13	1.01 ∓ 0.02	5.19 ∓ 0.15	0.09 ∓ 0.14 insig.	0.09 ∓ 0.04 sig.	0.18 ∓ 0.17 insig.	Plants, fairly well-developed
IV	3.18 ∓ 0.45	0.80 ∓ 0.15	3.98 ∓ 0.60	—0.91 ∓ 0.43 sig.	—0.12 ∓ 0.15 insig.	—1.03 ∓ 0.61 insig.	Leaves, green; older leaves dry
V	4.07 ∓ 0.42	0.99 ∓ 0.07	5.00 ∓ 0.41	—0.02 ∓ 0.42 insig.	0.07 ∓ 0.08 insig.	0.05 ∓ 0.42 insig.	Leaves, green; older leaves, and leaf tips dry

TABLE 8

Effects of 4-salt and 3-salt solutions upon the growth and development of lowland rice plants in the vegetative stage (Experiment from October 30 to December 18, 1940; data are averages of triplicate cultures)

CULTURE NO.[a]	STATISTICAL DIFFERENCE FRO.. CONTROL						INITIAL PH CONCENTRATION	HEIGHT OF PLANT	LENGTH OF ROOT	NUMBER OF TILLERS	APPEARANCE OF PLANTS AT HARVEST
	KH_2PO_4	$Ca(HPO_4)_2$	$(NH_4)_2SO_4$	$Ca(NO_5)_2$	KNO_3	$MgSO_4$		*cm.*	*cm.*		
I	0.00025	—	0.00025	0.00025	—	0.00125	5.50	61.8	24.7	6.3	Plants, healthy and vigorous
II	0.00025	—	0.000375	0.00037	—	0.001	5.70	60.3	22.5	7.3	Plants, fairly well-developed
III	0.00025	—	—	0.0005	—	0.00125	5.60	55.4	26.6	4.0	Leaves, chlorotic; culms, soft; several leaves, dry
IV	0.00025	—	—	0.0005	—	0.00125	4.50	49.7	27.0	5.0	Same as culture III
V	—	0.001	—	0.001	0.01	0.001	3.85	62.7	24.9	5.3	Leaves, very light green; a few dried leaves
VI	0.0016	—	—	0.003	—	0.008	4.20	49.0	28.8	5.7	Same as culture III

[a] Culture I received manganese and zinc at the rate of 10 p.p.m. each.
Cultures II and III received no trace element.
Cultures IV to VI received $MnSO_4$, 0.2 per cent; borax, 0.17 per cent; $ZnSO_4$, 0.08 per cent; $CuSO_4$, 0.06 per cent; iron sulfate was added at the rate of 1.4 per cent.
Cultures I, II, III, each received $FePO_4$ at the rate of 1 ml. per liter.

TABLE 8 (continued)

CULTURE NO.[a]	DRY WEIGHT OF TOP	DRY WEIGHT OF ROOT	DRY WEIGHT OF WHOLE PLANT	SALT PROPORTIONS			PLANTS AT HARVEST APPEARANCE OF
				Dry weight of top	Dry weight of root	Dry weight of whole plant	
	grams	*gram*	*grams*	*grams*	*gram*	*grams*	
I	3.01 ∓ 0.13	0.73 ∓ 0.04	3.74 ∓ 0.17				Plants, healthy and vigorous
II	2.21 ∓ 0.10	0.56 ∓ 0.02	2.77 ∓ 0.08	—0.80 ∓ 0.16 sig.	—0.17 ∓ 0.04 sig.	—0.97 ∓ 0.19 sig.	Plants, fairly well-developed
III	1.44 ∓ 0.12	0.36 ∓ 0.01	1.80 ∓ 0.03	—1.57 ∓ 0.18 sig.	—0.37 ∓ 0.04 sig.	—1.94 ∓ 0.17 sig.	Leaves, chlorotic; culms, soft; several leaves dry
IV	1.22 ∓ 0.06	0.38 ∓ 0.01	1.60 ∓ 0.06	—1.70 ∓ 0.14 sig.	—0.55 ∓ 0.04 sig.	—2.14 ∓ 0.18 sig.	Same as culture III
V	1.95 ∓ 0.32	0.52 ∓ 0.02	2.47 ∓ 0.34	—1.06 ∓ 0.85 sig.	—0.21 ∓ 0.04 sig.	—1.27 ∓ 0.38 sig.	Leaves, very light green; a few dried leaves
VI	1.14 ∓ 0.14	0.33 ∓ 0.02	1.47 ∓ 0.12	—1.87 ∓ 0.19 sig.	—0.40 ∓ 0.04 sig.	—2.27 ∓ 0.21 sig.	Same as culture III

DETERMINATION OF FURFURAL FROM SOME FARM BY-PRODUCTS [1]

SILVERIO M. FONTILLAS

Extensive work on furfural from corncobs, oat hulls, citrus fruit, cotton-seed-hull bran, different species of wood, and other sources has been done in the United States, Japan, Australia, Germany, and elsewhere, but only one such work (De Leon and Reyes, 1938) on some agricultural products has been reported in the Philippines. An exploratory study on the furfural analysis of some likely farm by-products in the Philippines as well as on the more common method of analysis will, therefore, be of some importance. Hence determination of furfural from some farm by-products was conducted.

Review of literature

Reed and Liepsner (1917) report that different lots of rice varied in hull content from 18.7 to 20.9 per cent, and in bran content from 10 to 11.7 per cent. In the Philippines rice hull in mills constitutes about 28.05 per cent; and bran, 6.50 per cent (West and Cruz, 1933). It may be seen therefore that rice hull which is a potential source of furfural constitutes the great bulk of rice by-products, the major portion of which goes to waste.

Porvier and Gortner (1923) proposed the volumetric method of determining furfural. The method involves electrometric titration with an acidified potassium bromide and potassium bromate solution. A similar method was proposed by Powell and Whittaker (1924) who used an excess of the bromide-bromate solution.

Kline and Acree (1932) compared the accuracy, efficiency, and degree of difficulty encountered among the standard phloroglucinol method, the thiobarbituric acid method, and the excess bromine method. These authors concluded that the excess bromine method is the better method to employ in the determination of the furfural in the distillate. Their findings were corroborated by Iddles and Robbins (1933), who, however, claimed that steam distil-

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[1] Experiment Station contribution No. 1436. Prepared in the Department of Agricultural Chemistry under the directions of Associate Professor A. I. de Leon and Instructor J. K. Demeterio.

lation gave a higher recovery of furfural. Sinclair and Bartholomew (1935) corroborated the findings of Kline and Acree in all aspects. Enders, Saji, and Schneebauer (1938) are other workers who found the excess bromine method satisfactory.

Acharya (1937) recommends the phloroglucinol precipitation method with slight modifications in the analysis of plant materials admixed with soil. The modifications were designed to correct the effect of oxidizing substances present in the soil.

Mackney and Reynolds (1938) compared the two gravimetric methods and found the phloroglucinol less accurate than the thiobarbituric acid method. Sweeney (1924), conducting experiments along the same line on corncobs, reported the furfural content of the entire cob to be 22.42 per cent as analyzed by the phloroglucinol method, and 23.22 per cent by the thiobarbituric acid method.

De Leon and Reyes (1938) hydrolyzed some agricultural products by refluxing the samples for 25 hours at an acid concentration of 5 per cent, and then steam-distilled them. They found that the hydrolysis with 5 per cent by volume sulfuric acid in a solid-liquid ratio of 1:6 gave the best furfural yield. They obtained furfural yields of 6.96 per cent from coconut shells, 4.27 from coconut rachis and petioles, 4.18 from coconut husks, and 4.19 from rice hulls.

Killefer (1926), studying the commercial manufacture of furfural from oat hulls and corncobs, reports a yield of more than 10 per cent technical furfural from the oat hulls by hydrolyzing with 5 per cent sulfuric acid at a pressure of 60 pounds per square inch. Mains (1937) finds, however, that corncobs give the highest furfural yield among the common agricultural materials, with oat hulls nearly as high.

For a laboratory or semi-commercial scale of producing furfural, Gattermann (1938) advocates the use of 150 ml. concentrated sulfuric acid in 800 ml. of water for the hydrolysis of 300 grams of bran. He reports a yield of from 5 to 7 grams. In this scale of production, he used ether for the recovery of the furfural in the distillate, after neutralization with sodium carbonate and saturation with sodium chloride.

MATERIALS AND METHOD

The materials used in the study were rice bran, rice hull, rice straw, and corncobs. The rice bran samples consisted of four different grades. They were taken from different places, but the rice

variety from which they originated could not be determined. The rice bran grades were obtained from "Cono" and "Kiskisan" rice mills.

"Cono" rice bran. This bran consists of very fine particles and is very rich in food value. Rivera (1936) and Valdez (1938), in their feeding studies, designated this bran as the "standard rice bran" or simply "fine rice bran." According to chemical analysis (Rivera, 1936; Tirol, 1933; West and Cruz, 1933), this bran is rich in fat, protein, and carbohydrates, but low in crude fiber content.

Rice bran through a 40-mesh sieve. This consisted of rice bran which passed through a 40-mesh sieve. The particles were relatively fine, similar to those of the "Cono" rice bran. No chemical or proximate analysis was made on the newly prepared samples. However, the ten-month old samples of this bran were analyzed for their ash and organic constituents.

"Kiskis" rice bran. This is a very coarse grade of rice bran with an abundance of finely divided hulls. The hulls mixed with the bran proper vary in size ranging from fine to about one-fourth of the size of the hull. Besides the hull, the bran contains also partly broken grains, which vary in size. This bran is low in fat and protein content, but high in ash and crude fiber; the carbohydrate content is less than that of "Cono" rice bran (Rivera, 1936). The furfural content of this bran was determined without separating the hulls and the partly broken rice grains.

Whole rice hulls. Whole rice hulls were used. They varied in color, shape, composition, feel to the hands, etc., depending upon the variety of rice from which they originated. They were light yellow to straw colored and devoid of awn or hair.

Rice hulls mixed with broken rice grains. Another kind of rice hull used was fine hulls mixed with broken grains. This sample was prepared in coincidence with the preparation of the rice bran sample passing through a 40-mesh sieve. The portion retained by this sieve was passed again through a 30-mesh sieve. The fine portion passing through was discarded and the portion retained was the fine rice hulls which contained many small broken rice grains, or "binlid".

Rice straw, or stalks. Two kinds of rice straw were used. Both of these were mature rice stalks gathered from the Experi-

ment Station fields of the College of Agriculture in December, 1939. These did not include the stems of the rice panicles or rachis. Another batch was collected in April, 1940. This carried with it the rachis.

Both of these batches of straw were dried in the sun and then chopped to fine pieces, ranging in size from about 0.1 to 0.5 centimeter. The chopped materials were further dried and then kept in 1,000 ml. Erlenmeyer flasks for future analyses.

Corncobs. Corncobs were used with the object of obtaining results as a check for the estimation of furfural in the rice materials that were used. Sweeney (1924) reports that the furfural yields of the corncobs is practically constant regardless of the age of the cob or the locality in which it was grown. However, no analysis on the furfural content of corncobs was done with the volumetric method. Since the volumetric, or excess bromine method was adopted in the present work, it was thought best to use corncobs as a check. The cobs were divided into pieces as big as the kernels or smaller and analyzed whole without separating the chaff, the woody portion, and the pith from each other.

Analytical procedure

The standard method of the Association of Official Agricultural Chemists (1935) with the modification suggested by Porvier and Gortner (1923) was followed in the distillation of furfural from the samples. The different samples were analyzed for their ash, crude protein, ether extract, and crude fiber content according to the official methods of the Association of Official Agricultural Chemists (1935). The nitrogen-free extract was determined by difference. No proximate analyses were made on the newly prepared samples of the bran passing through the 40-mesh sieve, and the rice straw without the rachis.

Recovery of furfural

The method used was that proposed by Gattermann (1938). The stored rice bran and the "Cono" and "Kiskis" brans, the whole hulls, the straw without the rachis, and the corncobs were subjected to this treatment.

RESULTS AND DISCUSSION

The results of the experiments are presented in four tables. All percentages in these tables are based on the dry weight of the samples.

Furfural content of materials studied

Rice bran. The furfural content (table 1) of rice bran passed through a 40-mesh sieve was 17.25 ± 0.140 per cent. The corresponding value for the same sample which had been stored for ten months was 10.55 ± 0.038 per cent. It appears that the bran suffered a loss in its furfural content, probably caused by deterioration, during storage. This is an interesting sidelight on the subject. Although there was no special effort to determine the effect of storage on the furfural content of the materials, the difference between those two samples is highly indicative of the behavior of the furfural in the bran stored. These data indicate a good deal of difference in the stability of furfural in rice bran from that of furfural in corncobs. As stated in the early part of this paper, Sweeney (1924) found that the furfural yield of corncobs is practically constant, regardless of the age of the cob or the locality where it was grown.

The "Cono" rice bran gave 6.32 ± 0.052 per cent furfural; and the "Kiskis" rice bran, 9.83 ± 0.097 per cent.

Table 2 shows that the differences between any pair of furfural values corresponding to the different rice bran samples are significant. In the descending order these samples may be arranged as follows: rice bran passing through a 40-mesh sieve (new), the same sample (stored for 10 months), "Kiskis" rice bran, and "Cono" rice bran. The differences between the pairs with the exception of the 10-month stored and the "Kiskis" rice brans are quite marked. They can be attributed to differences in the chemical composition of the brans, as will be shown later.

Rice hull. The furfural yield of the whole rice hulls was found to be 13.79 ± 0.136 per cent. This figure is lower than 17.05 ± 0.175 per cent, the furfural yield of rice hull mixed with broken rice grains. The difference might be attributed to the difference in composition as the particles of the kernels mixed with the hulls would appreciably modify the composition of the sample. This however, is not borne out by the proximate analysis of the two samples. An inspection of table 1 shows that no appreciable difference existed between the two samples in their composition. The only possible explanation is that the carbohydrate portion of the kernel particles was higher in furfural fraction than that of the whole hull. It was high enough to bring up the combined furfural content of the mixed components to a comparatively high value.

Rice straw. The furfural yield of the rice straw without the rachis was 12.97 ± 0.118 per cent, that of the straw with the rachis was 16.58 ± 0.091 per cent. The difference in furfural content between the two straw samples is significant (table 2). It would appear that the rachis portion of the straw had a comparatively higher concentration of furfural than the rest. The magnitude of the difference between the two furfural figures indicates that the rachis portion was quite rich in furfural, considering that in the mixed sample, the rachis fraction constituted only approximately from one-fourth to one-third by weight.

Corncobs. As already stated, corncobs were included among the materials analyzed for furfural, principally to serve as the reference standard in judging the suitability of the other materials as a source of furfural as well as a check on the method of analysis used. From table 1 it may be seen that the furfural content was 25.45 ± 0.097 per cent. This figure is higher than those reported by Sweeney (1924). The latter's figures range from 22.11 to 22.80 per cent with the phloroglucinol method and from 22.72 to 23.61 per cent with the thiobarbituric method. Because of lack of other necessary data, the value obtained in the present studies and those reported by Sweeney could not be compared statistically. The difference between these values is quite small, however.

Comparison between the groups of materials studied (table 2)

A cursory examination of the table would suggest that the corncobs were the highest in furfural content. Coming next were the rice bran passing through a 40-mesh sieve (not stored) and rice hull mixed with broken grains. These had the same furfural content. Of these two, the rice bran sample will very likely show the more consistent furfural analysis, disregarding the deterioration resulting from storage. This is quite apparent from the fact that the comparatively high yield of the mixed hull sample was due to the mixed broken kernels. Within limits, therefore, the furfural content will vary according to milling conditions, which would influence the amount of the kernel fraction in the mixture.

Next highest in furfural was rice straw with the rachis. Its difference from either the new rice bran or the mixed hulls was so small that it was barely significant. All the rest are comparatively poor in furfural. According to the descending order of

their furfural contents, they may be enumerated as whole rice hulls, rice straw without the rachis, the 10-month stored rice bran, "Kiskis" rice bran, and "Cono" rice bran.

Among the materials studied, the writer believes that only the corncobs, new rice bran, mixed hulls, and straw with the rachis might be suitable for commercial purposes. The rest contain furfural in amounts that may not be sufficient to make recovery profitable with the present-day methods of recovery.

Reliability of the method

The criterion used for the comparative reliability of the method of analysis on the different materials was the coefficient of variation.

Examination of table 1 reveals that a high degree of consistency in results was attained with all the materials used in this study. The coefficient of variation ranged from 1.44 ± 0.027 to 4.47 ± 0.115. The minimum values indicating the highest degree of reliability were obtained from the stored rice bran and the corncobs. The rice straw with the rachis gave an intermediate value. The rest closely approximated the maximum value. The range of the coefficient of variation, however, is fairly narrow, and in the absence of an exact quantitative method of comparison, it may be said that, in general, the excess bromine titration method employed in this study was equally applicable to the materials used. The low maximum (less than 5 per cent) coefficient of variation would seem to indicate that the method has a promise of wider application with a degree of consistency approximating the range found in this study. This deduction is strengthened by an examination of table 1. This table shows that no correlation occurred between the coefficient of variation and the composition of the samples. Subsequently it is reasonable to expect that the same magnitude of reliability measure will be attained when applied to other plant materials.

The accuracy of the method has been recognized by a number of investigators (Kline and Acree, 1932; Iddles and Robbins, 1933; Sinclair and Bartholomew, 1935; Acharya, 1937) who used different materials. As has been stated earlier, the furfural analysis of corncobs agrees quite well with that reported by Sweeney (1924), who used the standard precipitation method. Since about the same degree of reliability was obtained with the other materials as with the corncobs in the present study, it follows that the method applied equally well to all.

Correlation between furfural and other constituents

An interesting correlation existed between the furfural content and the crude proteins, ether extract, and total carbohydrate contents of the samples. Table 3 shows that high values of furfural were accompanied by low values of crude protein and ether extract and high values of total carbohydrates, that is, there was a negative correlation between the furfural and crude protein or ether extract, and a positive correlation between the furfural and total carbohydrates. These correlations are statistically significant. Insignificant correlation was found between furfural and crude fiber and between furfural and nitrogen-free extract.

It is reasonable to expect a positive correlation between the furfural and the total carbohydrate contents, since furfural itself is among the substances grouped under the general term "carbohydrates."

The apparent existence of a correlation between furfural and other organic constituents, however, is not quite as markedly significant as the fact that this correlation quantitatively held even with the comparatively few materials studied. The relatively more rigid test for statistical significance required for the few samples that was satisfied by this study indicates strongly that the same correlation may be found to exist among the great number of other related materials.

Recovery of furfural

The results of the tests for the recovery of furfural by Gattermann's method are shown in table 4. It may be seen that the percentage recovery was quite low in all the samples tried, ranging from mere traces in "Cono" rice bran to 3.55 in corncobs. Comparison with the theoretical amounts of furfural in those materials shows that the method proved to be not only inefficient but also erroneous. The materials that had a higher furfural content by analysis did not give correspondingly higher yields, as they were expected to do. Thus the furfural recovery percentage of theoretical yield ranged from traces in the "Cono" rice bran to 23 per cent in the straw. The method appears to favor smaller weights of samples used, necessitated by the bulk of these samples. It seems to fail entirely when the furfural content of the sample is 6.5 per cent or less. The writer does not believe that the results in this aspect of the present study are a good basis for conclusions regarding the possibility of the materials for industrial production of furfural.

The Gattermann method was not equally applicable on all the materials. Probably it needs slight modifications in each individual case to give comparable efficiencies.

SUMMARY

1. Four types of rice bran, two of rice hulls, two of rice straw, and corncobs, which are considered by-products of the farm, were analyzed for their furfural contents by the excess bromine titration method.

2. The furfural contents of the materials follow: corncobs, 25.45 per cent; new rice bran, 17.25 per cent; rice hull mixed with broken kernels, 17.05 per cent; rice straw with rachis, 16.58 per cent; whole rice hulls, 13.79 per cent; stored rice bran, 10.55 per cent; "Kiskis" rice bran, 9.83 per cent; and "Cono" rice bran, 6.32 per cent.

3. The excess-bromine titration method was equally applicable on all the materials studied, the coefficient of variation ranging between 1.44 and 4.47 per cent, which is a narrow range. The analysis of corncobs which served as the control indicated that the method is at least as accurate as the present standard method by precipitation.

4. A statistically significant negative correlation existed between the furfural and the crude protein contents and between the furfural and ether extract contents; a positive correlation was found to exist between the furfural and total carbohydrate contents.

5. Poor yields of furfural from 0 to 23 per cent of theoretical yield were obtained by the use of Gattermann's method. The results were not concordant.

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TABLE 1

Average composition of the materials studied

MATERIALS	DRY MATTER	FURFURAL CONTENT OF DRY MATTER [a]	PROXIMATE ANALYSIS OF DRY MATTER				
			Ash	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1. *a.* Rice bran passing through a 40-mesh sieve		17.25 ± 0.140 (4.22 ± 0.099)					
b. Same bran as in *a* stored for ten months	98.60 ± 0.082	10.55 ± 0.038 (1.44 ± 0.027)	19.38 ± 0.210	10.02 ± 0.200	7.12 ± 0.300	33.26 ± 0.370	29.99 ± 0.500
c. "Cono" rice bran	89.90 ± 0.092	6.32 ± 0.052 (4.03 ± 0.037)	10.06 ± 0.013	14.55 ± 1.813	20.99 ± 0.104	8.77 ± 0.047	45.14 ± 0.712
d. "Kiskis" rice bran	89.65 ± 0.053	9.83 ± 0.097 (4.19 ± 0.068)	16.97 ± 0.097	5.82 ± 0.147	7.96 ± 0.066	32.08 ± 0.200	37.13 ± 0.255
2. *a.* Whole rice hull	95.68 ± 0.115	13.79 ± 0.136 (3.95 ± 0.096)	24.91 ± 0.087	2.19 ± 0.076	2.69 ± 0.146	49.22 ± 0.213	20.67 ± 0.444
b. Rice hull mixed with broken grains	97.23 ± 0.089	17.05 ± 0.175 (4.47 ± 0.115)	22.83 ± 0.088	2.31 ± 0.118	3.06 ± 0.108	49.44 ± 0.345	21.57 ± 0.359
3. *a.* Rice straw without the rachis		12.97 ± 0.118 (3.64 ± 0.083)					
b. Rice straw with the rachis	88.95 ± 0.104	16.58 ± 0.091 (2.26 ± 0.064)	18.61 ± 0.086	2.64 ± 0.397	5.05 ± 0.216	35.13 ± 0.216	38.79 ± 0.088
4. Corncobs	90.78 ± 0.018	25.45 ± 0.097 (1.62 ± 0.068)	1.62 ± 0.045	1.82 ± 0.265	3.16 ± 0.152	35.58 ± 0.259	57.66 ± 0.140

[a] The figures in parentheses are the coefficients of variation with their standard errors.

TABLE 2

Comparison of the furfural content of the materials studied

MATERIALS	PAIR	FURFURAL CONTENT	DIFFERENCE
		per cent	*per cent*
1. Rice bran passing through a 40-mesh sieve	1:6	17.25 ± 0.140	0.20 ± 0.221 (I)
2. Same bran as in *1* stored for ten months	2:7	10.55 ± 0.038	2.42 ± 0.124 (S)
3. "Cono" (fine) rice bran .	3:4	6.32 ± 0.052	3.51 ± 0.103 (S)
4. "Kiskis" (coarse) rice bran	4:2	9.83 ± 0.097	0.72 ± 0.098 (S)
5. Whole rice hull	5:7	13.79 ± 0.136	0.82 ± 0.136 (S)
6. Rice hull mixed with broken rice grains	6:8	17.05 ± 0.175	0.47 ± 0.215 (S)
7. Rice straw without the rachis	7:8	12.97 ± 0.118	3.61 ± 0.148 (S)
8. Rice straw with the rachis		16.58 ± 0.091	
9. Corncobs	9:1	25.45 ± 0.097	8.20 ± 0.189 (S)

(S)—Significant
(I)—Insignificant

TABLE 3

Correlation of the furfural content and the proximate analysis of the different materials

MATERIALS	FURFURAL CONTENT	CONSTITUENTS CORRELATED WITH THE FURFURAL CONTENT				
		Crude protein	Ether extract	Crude fiber	Nitrogen free extract	Total Carbohydrates
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1. *b.* Ten-month old rice bran passing through a 40-mesh sieve	10.55	10.02	7.12	33.26	29.99	63.21
c. "Cono" rice bran	6.32	14.55	20.99	8.77	45.14	53.91
d. "Kiskis" rice bran	9.83	5.82	7.96	32.08	37.13	69.21
2. *a.* Whole rice hull	13.79	2.19	2.69	49.22	20.67	69.89
b. Rice hull mixed with broken grains	17.05	2.31	3.06	49.44	21.57	71.11
3. *b.* Rice straw with the rachis	16.58	2.64	5.05	35.13	38.79	73.92
4. Corn cobs	25.45	1.82	3.16	35.58	57.66	93.24
r = Coefficient of correlation		—0.786 (S)	—0.746 (S)	—0.524 (I)	+0.310 (I)	+0.956 (S)

(S)—Significant
(I)—Insignificant

TABLE 4

Average recovery of furfural

	FURFURAL RECOVERED	THEORETICAL FURFURAL CONTENT	RECOVERY PER CENT THEORETICAL
	per cent	*per cent*	
Bran, passing through 40-mesh sieve ...	1.19	17.25	6.89
"Cono"	—	6.32	—
"Kiskis"	0.57	9.85	5.80
Hulls	1.01	13.79	7.32
Straw	2.99	12.97	23.05
Corncob	3.55	25.45	13.95

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AN ECONOMIC AND SOCIAL SURVEY OF SUGAR CANE TENANCIES ON THE CALAMBA SUGAR ESTATE, LAGUNA [1, 2]

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WITH SIX TEXT FIGURES

While a number of studies have been made of tenancy on rice farms, practically no study has been made of tenants on sugar cane haciendas. Hence an economic and social survey of sugar cane tenancies on the Calamba Sugar Estate at Canlubang, Laguna, was made.

A number of workers, however, have made studies of cost of producing cane.

Velmonte (1938) stated that in an undeveloped country like the Philippine Islands where a vast unsettled public domain and a liberal land policy exist, the extent and increase of tenancy is without justification. He pointed out that tenancy in this country is not only an economic but also a social problem. He advanced possible solutions; namely, (*a*) organized land settlement under government direction, (*b*) state purchase of large estates for tenants, and (*c*) a rational program of economic and social rehabilitation of tenants.

Dalisay (1937), in his survey of rice tenancies in Cabiao, Nueva Ecija, found that the labor income of a rice tenant was ₱101.32. He also pointed out that the tenants stayed on their farms for an average of 11.10 years and that the length of tenure was directly related to age of tenant.

Valera [4], in his report read before the first Philippine Sugar Association convention, placed the cost of production of sugar cane at ₱187.00 per hectare, or ₱2.50 per ton of cane.

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[1] Experiment Station contribution No. 1637. Permission for the publication of this paper was granted by the management of the Calamba Sugar Estate.

[2] The writers wish to acknowledge with thanks the wholehearted coöperation of the management of the Calamba Sugar Estate in making possible this study, the many courtesies extended them, the valuable data that were gladly furnished, and the constructive suggestions made in improving and correcting the manuscript. Likewise the writers wish to thank the tenants who have given generously of their time to make this study possible.

[3] Now with the Department of Soils.

[4] VALERA, J. A. 1923. Report of the committee on labor for Luzon. Philippine Sugar Association Annual Report 1: 100–115.

Locsin [5] reported that in Negros the cost of production per hectare of fertilized cane was ₱359.00.

Catambay and Segovia (1933), in their study of the cost of production of sugar cane in the College of Agriculture farm, gave the cost of production of plant cane at ₱207.58 per hectare, or ₱4.57 per ton, and ratoon at ₱88.25 per hectare, or ₱4.79 per ton.

Gianzon [6] in his study of fertilization of sugar cane in the College of Agriculture, found that the cost of production of fertilized plant cane was ₱325.88 per hectare.

METHODS

Plan of the work

With the permission and coöperation of the Calamba Sugar Estate Management, a general survey of the entire farm was made in the month of April, 1938, with a view of laying the groundwork of the study. Altogether there were 268 tenants on the Estate distributed into 12 sections or barrios as follows:

Lagundi	35
Calamias	14
Pansol	10
Mañugmit	59
Pittland	28
Barrio No. 2	23
Barrio No. 3	14
K — field	15
Santo Domingo	16
Makinangapoy	24
Biñan	18
Malamig	12
Total	268

A random selection of tenants was made from six widely scattered sections, believed to be fairly representative; namely, Lagundi, Mañgumit, Pittland, Barrio No. 2, Barrio No. 3, and Biñan. Nine tenants were included in Lagundi, 19 in Mañgumit, 9 in Pittland, 7 in

[5] LOCSIN, C. L. 1930. Central and planter and systems on payment for cane. Sugar News 11: 601–608.

[6] GIANZON, A. C. The effect of the application of 350 kilograms of ammonium sulfate in the yield, cost, and income from trial plantings of sugar cane in the College of Agriculture. (Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture. 1938. Unpublished.)

Barrio No. 2, 5 in Barrio No. 3, and 5 in Biñan, or a total of 54 tenants representing a little over 20 per cent of the total.

With the coöperation of section inspectors, visits throughout the period of the survey were made to each of the fifty-four tenants included in the study. An inventory of the tenant's farm property was made during the first visit. During the subsequent visits made on week-ends the tenant was asked the progress of the work especially in connection with the various farm operations accomplished. During April and May, 1939, final visits were made to each tenant farmer. A concluding inventory of his farm property was taken and expenses together with miscellaneous receipts recorded. Mimeographed forms especially made in the Department of Agricultural Economics for a sugar cane tenancy survey facilitated the work of recording the progress of the study.

Information from tenants was supplemented and checked with that obtained from the management whose records were placed at the writers' disposal.

DISCUSSION OF RESULTS

The farm

The Calamba Sugar Estate has an area of 7,284.5 hectares. It has a population of 9,497. It is divided into 12 sections which are placed under the direct supervision of a field inspector with one or two assistants who look after the work of the tenants. The number of tenants found in each varies according to the area of each section. Four municipal governments have civil jurisdiction over the land of the Estate. These are Biñan, Santa Rosa, Calamba, and Cabuyao. The total area covered in this survey was 356.04 hectares of which 347.44 hectares were in plant cane, and the remaining 8.6 hectares in ratoon cane. In terms of total area of sugar land of the Estate of 4,128 hectares, the area covered by the study represented 8.6 per cent; but the area planted to cane each year was reported as only approximately 2,600 hectares, and the area in cane covered by the study, therefore, represented 13.7 per cent. The area devoted to plant cane by the 54 tenants ranged from 1.5 to 11.4 hectares, or an average of 6.43 hectares per tenant. Seven tenants planted ratoon cane ranging from 0.8 to 1.9 hectares, or an average per tenant of 1.22 hectares.

Crops raised

The major crop was sugar cane. The Estate had 4,127.87 hectares devoted to sugar cane. Of these approximately 2,600 are in

cane every year while the balance is fallowed and planted in the succeeding year. A large portion of the area of the Estate is planted to coconuts, the Estate operating a desiccated coconut factory for the effective disposal of the product. Rice to some extent was rotated with sugar cane. Other supplementary crops raised were vegetables, pineapple, cassava, corn, and bananas, most of which were grown in garden lots allotted each tenant and in backyards. In some sections of the Estate, tenants had community gardens which were well fenced with wire and amply supplied with water. It is well to note in this connection that the management encouraged the tenants to have good vegetable gardens so as to adequately supply themselves with vegetables which otherwise they would have to buy. Furthermore, efforts were made to induce tenants to raise poultry with the same objectives. The Estate had already a poultry project which it hoped would serve as foundation stock.

Lease contract

Nature. The contract between the Estate and the tenants was written, signed by both parties and two witnesses, and sworn in before a notary public. It was written in English with a corresponding Tagalog version. In case, however, of incompatibility between the two, the English text governs the interpretation.

Duration. The contract is for three consecutive crop years, automatically renewed for another three years if the tenant fails to give notice of leaving a year before the termination of the contract.[7] Even if due notice has been given by the tenant, the contract is automatically extended for one crop year for every year that the production of plant cane falls below 40 tons and the production of ratoon cane, below 30 tons a hectare, or if during the liquidation the tenant is not able to pay in cash all his indebtedness.

Terms. The Estate has the right to dismiss a tenant any time for sufficient cause as the non-performance by the tenant of his duties, disobedience or disregard of the rules and regulations of the Estate, failure to make a reasonable effort to carry out instructions, and willful destruction of Estate property. In case of flood, typhoon, earthquake, or other calamities beyond the control of the Estate which affect its ability to mill the cane, the Estate is not held responsible

[7] Effective with the 1941-42 crop, the former three-year contract has been shortened to one year and the clause pertaining to automatic extension has been eliminated.

if it cancels the agreement and fails to harvest and pay for the sugar cane of the tenant. The Estate may also cancel the agreement after paying for whatever work has been done, if during the period of the contract, the United States imposes an import duty or tariff against Philippine sugar or if any export tax should be collected on sugar shipments leaving the Philippines.

The tenant is assigned lots of which generally one-half to two-thirds are devoted to sugar cane culture.

The Estate provides the tenant with a commodious house. The houses are furnished free except for a few old ones which have long been constructed at the joint expense of the tenant and the management. Proper repairs are borne by the tenant.

All tools, equipment, implements, or other materials are furnished by the tenant. When the tenant does not have the necessary work animals, he gets them from the management. The price of whatever work animals he may get, however, is charged to his account. No interest is charged to the tenant for any advances, including those for the purchase of animals and equipment. The ownership of the animal remains with the Estate until after the full price has been paid.

Land preparation, planting, cultivation, and other cultural operations including fertilizing up to the time of maturity of the cane are performed by or at the expense of the tenant who is obliged to keep all cane area always in the best of conditions.

In case the work of the tenant has been completed and the management requires him to work with his own animal and implements on some other task outside of his farm, the tenant is paid ₱1.50 per day. If the work animal used by the tenant has not been fully paid, he receives only ₱0.80 per day and the ₱0.70 is credited against his indebtedness for work animals.

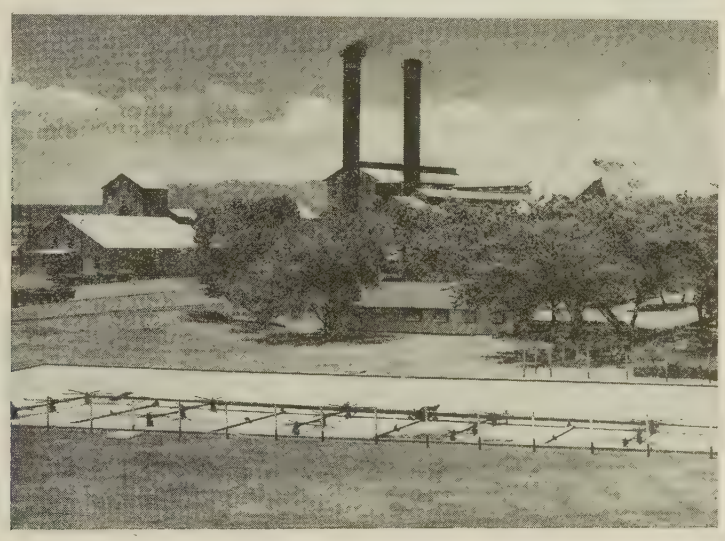
In order to do his planting work at the proper time, the tenant has to prepare and plant a portion of his fallow land during October of each year as the initial step in the preparation of a seed bed for the following year. If he fails to carry out this seed bed program and as a result lacks seeds for his planting, he buys them from the Estate at a price not exceeding ₱10.00 per "lacsa", or 10,000 seed pieces.

One half of the cost of fertilizer applied by the tenant is borne by the Estate.

During the term of the contract and provided the work of the tenant is done satisfactorily, advance payments are made at bi-weekly

periods in cash and in kind. For each tenant and wife ₱2.00 in cash and 5 gantas of rice per week are advanced. For each child 16 years old or over, 2.5 gantas per week; for each child between 10 and 16 years old, 1 ganta; for 2 children between 5 and 10 years old, 1 ganta; and for additional help, 2.5 gantas per week. Special advances are given the tenant upon presentation of a stisfactory report of the condition of his crop. All these advances do not bear interest but are charged to the account of the tenant.

Harvesting is entirely borne by the Estate. The tenant, if he so desires, may be present during the weighing of his harvested cane in person or have a duly authorized person to represent him.



Courtesy, Calamba Sugar Estate

Fig. 1.—The sugar factory, Calamba Sugar Estate.

Without charge, both the Estate and the tenant are to coöperate in checking fires and combating locusts and animal and plant diseases. whenever such contingencies occur.

Upon the termination of the contract, the tenant is not compensated for any improvement he makes on the farm.

For the work performed by the tenant, the Estate pays him ₱100.00 per hectare for plant cane and in addition a bonus of ₱1.00 per ton of cane in excess of 60 tons to the hectare on class "A" and 45 tons on class "B" lands. The sum of ₱45.00 per hectare is paid him on ratoon cane with an additional bonus of ₱1.00 per ton in case he produces more than 40 tons per hectare in class "A", and 28 tons

per hectare in class "B" lands.[8] Class "A" lands are those whose production of plant cane averages 70 tons per hectare, and class "B" those that produce, on the average, less than 70 tons to a hectare.

Each tenant who has served at least one complete contract period and has already signed a renewal contract, whose cane harvest averages the minimum tonnage requirement, and who has complied with all the conditions of the agreement is entitled to a "price bonus" of twelve and one-half centavos per ton of cane he has delivered if the

Courtesy, Calamba Sugar Estate

Fig. 2.—A large family is necessary to carry on the work on the tenant's farm.

Estate receives a net average price for its sugar of more than ₱7.50 per picul ex-Bodega, Canlubang.

The tenant receives two-thirds of whatever supplementary crop he may produce and gives one-third to the Estate after deducting one-fifth of the total for harvesting and threshing expenses, and one cavan seed, in the case of palay, for the following crop. He is, however, privileged to have all the vegetables and other garden crops that he may produce in the vegetable garden allotted him.

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[8] Effective with the 1939-40 crop, the Estate increased the cane payments: Plant cane ₱110.00 per hectare; ratoon cane, ₱50.00 per hectare. Bonuses were increased to ₱1.50 per ton cane on the same basis as above. These increased payments were extended to 1940-41 and 1941-42 crops. Future payments are to be decided not later than August 1, 1941.

In case a tenant is discharged for just cause or leaves at his own request, he is paid for whatever work he has performed. If his cane is "shaded in", or has undergone the final cultivation, and the lot is in good condition, he receives ₱100.00 per hectare of plant cane and ₱45.00 per hectare of ratoon cane. When his cane is not "shaded in", he is paid on the basis of the following schedule:

(*a*) Animal plowing and harrowing at the rate of ₱5.00 per hectare.
(*b*) Animal cultivation at the rate of ₱5.00 per hectare.
(*c*) Weeding at the rate of ₱12.00 per hectare.
(*d*) Furrowing and planting, ₱12.00 per hectare.
(*e*) Applying fertilizer, ₱1.00 per hectare fertilized.
(*f*) Hauling seed at the rate of ₱1.00 per hectare planted.

Courtesy, Calamba Sugar Estate

Fig. 3.—A community garden in barrio Lagundi, a tenant's home in the background.

Management and labor

Work of the tenants was under the direct supervision of the field inspectors of the Estate. The inspectors decided what work was to be done and on what portion of the tenant's field. The field inspectors took orders regarding the field work from the field manager and were directly responsible to him for all work on the farm as well as the general condition of the sections assigned to them. The cost of labor varied in the locality during the survey. The daily wage worker who performed operations as plowing, harrowing, and other

similar work using animal labor, was paid ₱0.80 per day. This was recently raised to ₱1.00. For operations, like weeding, hauling points, fertilizer application, and planting, the daily wage was based on the contract price per hectare. This was ₱12.00 a hectare for weeding; for hauling points, ₱1.00 a hectare; for fertilizer application, ₱1.00 a hectare; and for planting, ₱10.00 a hectare. The work of harvesting, hauling, and loading was given to a contractor at ₱1.25 per ton.

Distribution of labor by processes. Table 1 shows the labor requirements for the various field operations. Since ratoon cane production was insignificant, the present discussion refers only to plant

Courtesy, Calamba Sugar Estate

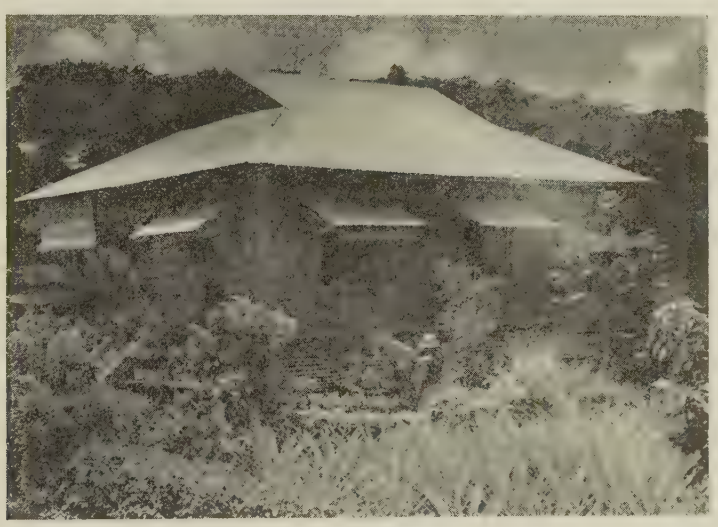
Fig. 4.—A tenant's home and garden, barrio Malamig.

cane. The total labor hour requirement on an average tenant farm area of 6.43 hectares was 11,134.70 hours for man and 3,529.23 hours for animal, or an average per hectare of 1,731.68 man hours and 548.87 animal hours, respectively.

Land preparation consisted of plowing, harrowing, and furrowing. Table 1 shows that plowing required 1,222.99 man and animal labor hours respectively, or an average of 190.20 hours per hectare. Usually plowing was done from three to five times. Harrowing followed every plowing. It required 295.46 man and animal labor hours respectively to finish 6.43 hectares, or an average of 45.95 hours per hectare. While plowing and harrowing were done by the tenant or

members of his household, furrowing was performed with the use of tractors owned by the Estate. The cost of this operation was charged to the account of the tenant. It required 28.94 man hours to furrow a tenant's holding of plant cane, or an average of 4.50 man hours to the hectare.

Seed pieces were prepared before the furrowing operations. Coöperative laborers together with some members of the tenant's household performed this work. Coöperative laborers were members of the tenants' households performing work mutually on the different tenant holdings. The number of hours devoted by the



Courtesy, Calamba Sugar Estate

Fig. 5.—An inspector's house, barrio Malamig.

coöperative laborers to all farm operations where such kind of labor was used, was found by computing the actual number of labor hours they contributed. It required 709.29 man hours per holding, or an average of 110.31 man hours per hectare. This was based on the time devoted to the preparation of seed pieces which were planted on 172.93 hectares. Additional seed pieces were secured from the Estate at ₱8.00 per ten thousand.

Hauling points required 133.10 man and animal labor hours respectively per plant cane holding, or an average of 20.70 hours per hectare. In most cases the work was done with the use of coöperative labor.

Planting was done by coöperative laborers together with members of the tenant's household. It required 624.10 man hours to plant 6.43 hectares, or an average of 97.06 man hours per hectare.

Replanting was done by the members of the household. It took 451.06 hours of man labor per plant cane holding, or an average of 70.15 man hours to the hectare.

Cultivation was performed very thoroughly. Offbarring was done from two to five times. This required 714.95 hours of man and animal labor per plant-cane holding, or an average of 111.19 hours per hectare while hilling-up which was performed from one to four times required 652.64 hours of man and animal labor per plant

Courtesy, Calamba Sugar Estate

Fig. 6.—An elementary school provided by the Estate, barrio Makinangapoy.

cane holding, or an average of 101.50 hours per hectare. The application of animal-drawn cultivator required 510.09 hours of man and animal labor per plant-cane holding, or an average of 79.33 hours per hectare.

Weeding required 2,195.46 hours of man labor per holding, or on the average, 341.44 hours to the hectare of plant cane. This work was done from two to six times.

Fertilizer application was done twice for plant cane. The first was during the planting and the second was just before the final hilling-up. Plant cane received 300 kilograms of ammonium sulfate fertilizer per hectare. The labor requirement for plant cane for this operation was, on the average, 27.00 man hours per hectare.

Harvesting, hauling, and loading canes were done by a contractor employed by the Estate. As mentioned elsewhere in this paper, the contractor was paid ₱1.25 per ton of cane harvested, hauled, and loaded on train cars at loading stations. The contractor paid all labor costs. Migratory labor was used in these operations. For harvesting alone, 240.00 hours of man labor were needed, on the average to finish a hectare. Hauling needed 144.00 hours per hectare. The labor hour requirement for loading plant cane was 148.35 hours per hectare.

Seasonal distribution of labor. Land preparation began in the month of September. Planting started in October and extended to the following February. The succeeding farm operations, cultivation, replanting, weeding, and second fertilization commenced as soon as the cane plants were of such height as to warrant the performance of cultural requirements. This was usually from February to July. The tenants started the cultivation of ratoons immediately after the cutting of the cane and continued until the fields were "shaded in". Harvesting was done from the month of November to March.

Farm investment

Dwellings. The investment in dwellings was ₱35.00 per tenant, or 6.77 per cent of the total investment (table 2). This very low figure was due to the fact that only fourteen tenants had houses built for their joint account with the Estate; the rest were living in houses furnished free by the Estate.

Farm buildings. The investment in farm buildings consisted of poultry houses and animal sheds. The average investment per tenant was ₱16.22, or 3.14 per cent of the total investment (table 2).

Tools and implements. The tools and implements of the tenants consisted of plows, harrows, bolos, hoes, bull carts, cultivators, sleds, and other implements required in the cultivation of sugar cane together with some tools for the culture of upland rice. The average investment in tools and implements was ₱152.54 per tenant, or 29.52 per cent of the total investment (table 2).

Work animals. Table 2 shows that the investment in work animals was the highest, averaging ₱280.13 per tenant, or 54.20 per cent of the total investment. The work animals consisted of carabaos and bullocks. The value of work animals listed by tenants included in the survey was ₱22,691.00, or ₱420.20 per tenant. Consider-

ing, however, that not all animals were fully paid for, this total figure if used would unduly raise the tenant's investment. Hence, it has been conservatively estimated that this indebtedness at the maximum would not exceed one third of the investment in work animals so that the total figure was reduced accordingly.

Livestock. Chickens and swine constituted the investment in livestock. This amounted to ₱22.28 per tenant, or 4.31 per cent of the total investment (table 2).

Farm produce and supplies. This consisted mostly of palay and corn. The average investment was ₱5.76, or 1.11 per cent of the total investment (table 2).

Seeds. This investment consisted of palay, corn, and vegetable seeds amounting to an average of ₱4.89 per tenant, or 0.95 per cent of the total investment (table 2).

Table 2 further shows that the total investment for all tenants amounted to ₱27,908.87, or an average of ₱516.83 per tenant. This investment was very much greater when compared with the investment of tenants working on rice lands which, according to Dalisy (1937) in his study of rice tenancies in Nueva Ecija, was ₱280.27.

Farm income and labor income

Farm income. The farm income was found by deducting from the total farm receipts the total farm expenses. Total farm receipts consisted of the cane payments or basic payments of ₱100.00 per hectare made by the Estate to the tenant for plant cane and ₱45.00 for ratoon together with bonuses. Total farm expenses were made up of cash expenses, non-cash expenses, and any decrease in inventory value.

Table 3a shows that the total receipts of a tenant farmer were ₱702.44. These were made up of ₱650.57 of basic or cane payments and ₱51.87 bonuses. Total farm expenses were ₱743.15 of which ₱226.86 were cash expenses, ₱487.09 non-cash expenses, and ₱29.20 decrease in inventory value. Cash expenses were made up of hired labor amounting to ₱30.32; fertilizer cost, ₱82.65; cost of seed taken from the Estate, ₱75.31; and cost of furrowing, ₱38.58. Non-cash expenses were made up of cost of food of hired labor amounting to ₱37.21; cost of seeds owned, ₱76.89; unpaid family labor, ₱122.80; coöperative labor cost, ₱52.02; and animal labor cost, ₱198.17. The cost of food of hired laborers was based on the value of their share

of the tenant's advances. This cost amounted to ₱49.00 for a helper for 14 months. Unpaid family labor did not include cost of the tenant's own labor. With expenses deducted from receipts, the farm income was found to be minus ₱40.71 per tenant.

Labor income. Table 3a shows that the average labor income was minus ₱101.45. This was found by deducting interest on investment at 7 per cent, the current bank rate on well-secured farm loans, for 14 months, from the farm income. The length of the crop year in the study was 14 months.

The negative farm and labor incomes were due, first, to the fact that the tenant operator, on the average, performed only 24.67 per cent of the total labor hour requirements of the farm (table 4). Members of the family did about 45 per cent of the labor. The remainder was done by coöperative and hired laborers. It is obvious that the labor cost was high, and consequently increased the farm expenses. The second cause of the negative farm and labor incomes was the thorough cultivation that was required of the tenant which raised the labor requirements on the farm. Catambay and Segovia (1933) pointed out that cane cultivation on the College farm required only 140.3 man and animal labor hours per hectare. Table 1 shows that in the present work, off-barring required 111.19 hours of man and animal labor each per hectare; hilling-up 101.50, hours; and use of animal-drawn cultivators, 79.33 hours per hectare, making a total of 292.02 hours per hectare of man and animal labor respectively, or more than twice the work of cane cultivation elsewhere. Consequently, farm expenses were raised to a high figure and lowered the labor income.

A better picture of the financial conditions of the tenants may be shown perhaps by their distribution according to farm and labor incomes as shown in tables 3b and 3c respectively.

It will be seen that 20, or 37.03 per cent of the tenants, had farm incomes and 34, or 62.97 per cent, had negative farm incomes (table 3b). Of the 20 tenants reporting farm incomes, 12 had farm incomes ranging from ₱50.00 to ₱149.00 and 4 had incomes from ₱200.00 to ₱300.00. On the other hand, of the 34 who reported negative farm incomes, 10 had from 0 to—₱49.00 and 16 had negative farm incomes ranging from—₱50.00 to as low as—₱249.00.

Again in table 3c it may be seen that only 15, or 27.77 per cent, had labor incomes to compensate them for their work whereas the majority, 39, or 72.23 per cent, showed negative labor incomes

indicating the unprofitableness of their farm operation. Of the 15 showing labor income, 9 had very low labor incomes not exceeding ₱49.00 and only 4 showed profitable operations with labor incomes ranging from ₱150.00 to ₱299.00. The situation, however, of the 39 tenants with negative incomes was shown by the fact that 21 had negative labor incomes ranging from ₱50.00 to as much as ₱199.00 and fully 15 more showed negative labor incomes of ₱200 or lower.

It is mentioned elsewhere in this paper that a tenant operator had a supplementary income of ₱100.23 (table 3a). While this was insufficient to compensate for the negative labor income, there were perquisites, many of which could not be evaluated in terms of money that were enjoyed by the tenant farmer and the members of his household which tended to ameliorate working conditions on the Estate. These were as follows:

(*a*) Advances were without interest.
(*b*) Artesian wells were constructed and maintained to supply safe drinking water.
(*c*) School system was free on the estate, 6 schools being maintained by the Estate at its own expense in 6 barrios or sections. Three other schools on the Estate were maintained by government, two of which were in the barrios and one on the Estate's mill site.
(*d*) Hospitalization and medical treatment were free with ambulance service at any time.
(*e*) Malaria control work was being done.
(*f*) All garden and poultry products belonged entirely to the tenants even though the Estate paid relatively high salaries to two men who supervised the gardening projects.

Furthermore, the value of garden crops and animal products contributed to the family living was considerable and this was not reflected in the labor income. While it would appear on the basis of farm and labor incomes that the tenant does not get paid for his labor, because of the fact that about 45 per cent of the labor expense was unpaid family labor, the supplementary income and many perquisites, which are not granted by other large plantations but were received by the tenant, nearly offset in amount the negative income. Garden crops and animal products of considerable quantity contributed to the family living tended to make the economic condition of the tenant far from miserable. In fact a general ocular survey of the homes and yards of tenant homes would convey an idea of prosperity and wholesome rural life.

Secondary occupations and household industries

Nature. While the tenants were engaged in the cultivation of sugar cane in the months of April to July, they devoted part of their time to the culture of upland rice. The area to be planted to rice by each tenant was determined by the Estate. Poultry raising, vegetable gardening, and to some extent hog raising were not uncommon enterprises among the tenants. In this connection it is interesting to note that the Estate encouraged tenants to raise chickens and vegetables, and even went to the extent of requesting men from the College of Agriculture, University of the Philippines, to lecture on poultry raising and vegetable gardening to the tenants. In some cases members of the household were employed by the Estate with pay in various kinds of farm labor.

Income. Table 3a shows that the supplementary income of a tenant farmer averaged ₱100.23. A large portion of this came from palay production. This amount did not include the value of vegetables, eggs, chickens, swine, fruit, and cassava supplied by the farm to the household. Dalisay (1937) reported that the supplementary income of rice tenants in Cabiao, Nueva Ecija averaged ₱66.81. This income is much lower than that of the sugar cane tenants included in this study.

Stability of tenure

The tenure ranged from 1 to 25 years, or an average of 10.45 years (table 5). It is further shown in table 5 that length of tenure was directly related to age of tenant.

The tenants were engaged in different occupations before working for the Estate. Some of them were farm hands in their home towns, others worked on the Estate's coconut plantation, and still others were either working as daily wage earners or as helpers to their fathers on the farm. There was no case of landownership among the tenants included in this study.

The household

Members and age. Table 6 shows that there were 561 members in the 54 households, or an average of 10.38 persons. It also shows that there were 380 members in the 54 families, or an average of 7.03 per family. There were, further, 181 other people in the household many of whom were related to the tenant. Some were helpers. They averaged 3.35 to a household. There was a

total of 275 children averaging 5.09 per family. The size of the household and family were greater than that reported by Velmonte, Sumagui, and Viray (1933), who gave size of a farm household as 5.65 persons and size of family as 5.12 persons. The number of persons to a tenant family was also greater than the average size of a Filipino family which, according to the census of 1918, was 4 persons per family. These large households were necessary in sugar cane farming in the Estate in view of the heavy labor requirements. Operators with small families would find themselves unable to cope with the work on the farm, averaging 6.43 hectares; hence, only those with large families and households could possibly work as tenants on the Estate.

Ages. The ages of the tenants ranged from 28 to 64 years, or an average of 47.88 years (table 5). The wives of the tenants ranged in age from 22 to 60, or an average of 42.07 years. The children ranged in age from a few months to as old as 32 years. Out of the 275 children, 214 were 10 years old or above.

The home

The homes of the tenants were tidy and clean. They were made of wood with galvanized iron roof and concrete foundations, except for six which were made of bamboo and roofed with either nipa or cogon. Most of the houses were new, and the old ones were in a good state of repair. The number of rooms varied from two to three. Many of the wooden houses had kitchens which were also made of wood and roofed with galvanized iron. The cost of the houses of strong-material ranged from ₱300.00 to ₱420.00 when new. The nipa and cogon houses cost ₱160.00 each to construct. The surroundings of these houses were clean and well arranged. In some cases front yards were planted to ornamental plants. In barrio sites, or wherever two or more houses were grouped, there was an artesian well. Electric light was used by tenants who were living near the Estate's mill site.

Literacy and education

Operator and wife. Table 7 shows the literacy of the tenant's family. Of the 54 tenants included in the study, only one could read and write both English and Tagalog, representing 1.85 per cent of the total; one could read and write Tagalog only also representing 1.85 per cent; 21, or 38.88 per cent, could read Tagalog

only; 31, or 57.41 per cent, could neither read nor write. Of the 51 tenant wives, one could read and write both English and Tagalog representing 1.96 per cent; 23, or 45.10 per cent, could read Tagalog only; and 27, or 52.94 per cent, could neither read nor write.

Children. Children ten years of age or over were considered in the determination of literacy. Of the 214 children who were ten years old or over, 136, or 63.55 per cent, could read and write both English and Tagalog; 12, or 5.61 per cent, could read and write Tagalog only; 15, or 7.01 per cent, could read only Tagalog; and 51, or 23.83 per cent, could neither read nor write.

The relatively high percentage of children who were able to read and write both English and Tagalog was largely due to the free school system furnished by the Estate. There were 9 primary schools located in convenient places all over the Estate. Graduates from the Philippine Normal School and high schools were employed as teachers. The highest grade in these barrio schools was the fifth grade.

SUMMARY

1. Included in this study were 54 sugar cane tenants distributed among six sections of the Calamba Sugar Estate, namely, Lagundi, Mañgumit, Pittland, Barrio No. 2, Barrio No. 3, and Biñan.

2. The total area of the holdings included in this survey was 356.04 hectares, of which 347.44 were planted to plant cane, or an average of 6.43 hectares per tenant holding, and 8.6 hectares to ratoon. Only seven tenants had ratoon cane with an average of 1.22 hectares each.

3. Lease contracts were written and definite. The land was furnished by the landowner. All houses were given free except for old ones which in the past were constructed at the joint expense of the tenant and the Estate. Work animals and tools were furnished by the tenant or advanced by the Estate and charged to the account of the tenant. Land preparation and other cultural requirements except harvesting, hauling, and loading were done exclusively by or at the expense of the tenant and subject to the direction of the Estate. Expenses for harvesting, hauling, and loading were borne by the Estate.

The tenant was paid ₱100 per hectare devoted to plant cane and ₱45 per hectare to ratoon. An additional bonus of ₱1.00 per ton was given the tenant if he exceeded the tonnage requirement,

which for plant cane was 60 tons to a hectare on class "A", and 45 tons on class "B" lands; and for ratoon was 40 tons to a hectare on class "A" land, and 28 tons on class "B".[9]

4. It required 1,731.68 man labor hours, and 548.87 animal labor hours to produce a hectare of plant cane. A hectare of ratoon cane required 1,133.05 man labor hours and 245.59 animal labor hours.

5. The average farm investment of a sugar cane tenant was ₱516.83. Of the total, the average investment in dwellings was ₱35.00; in farm buildings, ₱16.22; in tools and implements, ₱152.54; in work animals, ₱280.13; in livestock, ₱22.28; in farm produce and supplies, ₱5.76; and in seeds, ₱4.89.

6. The tenant's farm receipts were, on the average, ₱702.44. This consisted of cane payments and bonuses.

7. The tenant farmer's expenses for the cane crop amounted to ₱743.15. This included operating expenses, labor cost, excluding cost of his own labor, and decrease in inventory value.

8. The average farm income as found in this study was minus ₱40.71; and labor income, minus ₱101.45.

9. The average supplementary income of the cane tenant amounted to ₱100.23.

10. Tenants and members of their households enjoy the privileges of advances without interest, free school system, free medical treatment, and full ownership of poultry and garden products. They were also benefited by the maintenance and construction of artesian wells and the continuous work on malaria control undertaken by the Estate.

11. The length of tenure in the Calamba Sugar Estate of the tenants included in this study was, on the average, 10.45 years. The range was from 1 to 25 years.

12. There were 10.38 persons to a tenant household. The age of the tenants ranged from 28 to 64 years, or an average of 47.88 years; the tenant wives varied in age from 22 to 60 years, or an average of 42.07 years. The children ranged in age from a few months old to as old as 32 years. Out of the 275 children, 214 were ten years of age or above.

13. Except for six, the tenants' houses were strongly built of wood with galvanized iron roof.

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[9] See footnote 8.

14. Of the 54 tenants included in the study, one, or 1.85 per cent, could read and write both English and Tagalog; one, or 1.85 per cent, could read and write Tagalog only; 21, or 38.89 per cent, could read Tagalog only; 31, or 57.41 per cent, could neither read nor write.

Of the 51 tenant wives, representing 1.96 per cent one could read and write English, 23, or 45.10 per cent, could read Tagalog only; and 27, or 52.94 per cent, could neither read nor write.

Of the 214 children who were 10 years of age or above, 136, or 63.55 per cent, could read and write both English and Tagalog; 12, or 5.61 per cent, could read and write Tagalog only; 16, or 7.01, per cent, could read only Tagalog; and 51, or 23.83 per cent, could neither read nor write.

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TABLE 1

Labor hour requirements per tenant holding and per hectare [a]

FARM OPERATIONS	PLANT CANE				RATOON CANE			
	Man labor		Animal labor		Man labor		Animal labor	
	Per tenant holding	Per hectare	Per tenant holding	Per hectare	Per tenant holding	Per hectare	Per tenant holding	Per hectare
	hours	*hours*	*hours*	*hours*	*hours*	*hours*	*hours*	*hours*
Total	11,134.70	1,731.68	3,529.23	548.87	1,382.32	1,133.05	299.61	245.59
Cleaning	——	——			89.38	73.26		
Plowing	1,222.99	190.20	1,222.99	190.20				
Harrowing	295.46	45.95	295.46	45.95				
Furrowing [b]	28.94	4.50						
Preparing points [c]	709.29	110.31						
Hauling points	133.10	20.70	133.10	20.70				
Planting	624.10	97.06						
Replanting	451.06	70.15			61.56	50.46		
Off-barring	714.95	111.19	714.95	111.19	114.05	93.49	114.05	93.49
Hilling-up	652.64	101.50	652.64	101.50	104.15	85.37	104.15	85.37
Use of cane cultivator	510.09	79.33	510.09	79.33	81.41	66.73	81.41	66.73
Fertilizing	173.61	27.00			21.85	17.91		
Weeding	2,195.46	341.44			288.97	236.86		
Harvesting	1,543.20	240.00			292.80	240.00		
Hauling cane	925.92	144.00			175.68	144.00		
Loading cane	953.89	148.35			152.47	124.97		

[a] Computed on the basis of 54 tenant holdings planted to sugar cane (plant cane) with a total area of 347.44 hectares, or an average of 6.43 hectares, and of seven lots planted to ratoon cane with an area of 8.6 hectares, or an average of 1.22 hectares.

[b] Done by tractor.

[c] Points (seeds) owned by tenants and planted on an area of 172.93 hectares

TABLE 2

Farm investment of 54 tenant operators

	FOR ALL TENANTS	AVERAGE PER TENANT	PER CENT OF TOTAL
	pesos	*pesos*	
Tenant's dwelling	1,890.00	35.00	6.77
Farm buildings	876.00	16.22	3.14
Tools and implements	8,237.03	152.54	29.52
Work animals	15,127.34	280.13	54.20
Livestock	1,203.55	22.28	4.31
Farm produce and supplies	311.15	5.76	1.11
Seeds	263.80	4.89	0.95
Total investment	27.908 87	516.83	100.00

TABLE 3a

Farm income, labor income, and supplementary income of a tenant farmer Calamba Sugar Estate, 1938-1939 [a]

	pesos	*pesos*
Total farm receipts		702.44
Sugar cane payments	650.57	
Bonuses	51.87	
Total farm expenses		743.15
Cash expenses:		
Hired labor	30.32	
Fertilizer	82.65	
Seed	75.31	
Furrowing	38.58	
Non-cash expenses:		
Cost of food of hired labor	37.21	
Seed	76.89	
Unpaid family labor	122.80	
Coöperative labor	52.02	
Animal labor	198.17	
Decrease in inventory value	29.20	
Farm income		—40.71
Interest at 7 per cent on average farm investment for 14 months		60.74
Labor income		—101.45
Supplementary income		
Vegetables	8 93	
Chickens	10.42	
Swine	13.98	
Palay	58.47	
Pineapple	0.52	
Cassava	2.64	
Banana	0.81	
Earnings	2.04	
Miscellaneous	2.42	
Total supplementary income		100.23

[a] Computed on the basis of 54 tenant farmers working a total area of 356.04 hectares.

TABLE 3b

Distribution of sugar cane tenant operators according to farm income, Calamba Sugar Estate, 1938-1939

FARM INCOME	NUMBER OF TENANT OPERATORS	PER CENT OF TOTAL
pesos	*number*	*per cent*
300 and over	1	1.85
250 to 299	1	1.85
200 to 249	2	3.70
150 to 199	0	0
100 to 149	4	7.41
50 to 99	8	14.81
0 to 49	4	7.41
	20	37.03
0 to —49	10	18.52
—50 to —99	7	12.96
—100 to —149	4	7.41
—150 to —199	5	9.26
—200 to —249	4	7.41
—250 and over	4	7.41
	34	62 97
Total	54	100.00

TABLE 3c

Distribution of sugar cane tenant operators according to labor income, Calamba Sugar Estate, 1938-1939

FARM INCOME	NUMBER OF TENANT OPERATORS	PER CENT OF TOTAL
pesos	*number*	*per cent*
250 to 299	1	1.85
200 to 249	1	1.85
150 to 199	2	3.70
100 to 149	0	0
50 to 99	2	3.70
0 to 49	9	16.67
	15	27.77
0 to —49	3	5.56
—50 to —99	9	16.67
—100 to —149	8	14.81
—150 to —199	4	7.41
—200 and over	15	27.78
	39	72 23
Total	54	100.00

TABLE 4

Operator's labor and labor hour contributions of the tenant families, cooperative laborers, and hired laborers [a]

KIND OF LABOR	PLANT CANE		RATOON CANE	
	Number of hours	Per cent of total	Number of hours	Per cent of total
Family labor [b]				
Son	132,301.5	33.42	1,870.3	34.85
Brother	9,628.3	2.43		
Daughter	21,751.3	5.49	547.0	10.19
Wife	5,890.1	1.49	162.0	3.02
Niece	2,436.6	0.61		
Nephew	4,180.5	1.06		
Granddaughter	1,380.0	0.35		
Cooperative labor	51,021.2	12.89	48.0	0.80
Hired labor [c]	69,634.2	17.59	1,128.9	21.03
Operator's labor	97,659.3	24.67	1,610.9	30.02
Total	395,883.0	100.00	5,367.1	100.00

[a] Labor hour requirements for harvesting, loading, and hauling are not included.

[b] Forty-five tenant farmers had sons, three had brothers, thirty-two had daughters, twenty-one had wives, two had nieces, one had a nephew, and one had a grand daughter as helpers in the field work.

[c] Twenty-six tenant farms employed hired labor.

TABLE 5

Relation of age of operator to length of tenure

AGE OF OPERATOR	NUMBER OF OPERATORS		AVERAGE AGE OF OPERATOR	AVERAGE LENGTH OF TENURE
	number	*per cent*	*years*	*years*
For all tenants' holdings	54	100	47.88	10.45
20 to less than 30 years	1	1.85	28.00	3.00
30 to less than 40 years	7	12.96	34.14	6.85
40 to less than 50 years	22	40.74	45.36	10.70
50 to less than 60 years	20	37.04	53.75	11.45
60 and over	4	7.41	62 00	12.25

TABLE 6

Size of family and size of household

	FOR 54 FAMILIES	AVERAGE PER FAMILY
	number	*average*
Size of family	380	7.03
Operator and wife	105	1.94
Children	275	5.09
Other people in the home	181	3.35
Size of household	561	10.38

TABLE 7

Literacy of the family

MEMBER OF THE FAMILY	TOTAL NUMBER IN 54 FAMILIES	UNABLE TO READ AND WRITE		ABLE TO READ ONLY TAGALOG		ABLE TO READ AND WRITE TAGALOG ONLY		ABLE TO READ AND WRITE TAGALOG AND ENGLISH	
		number	*per cent*	*number*	*per cent*	*number*	*per cent*	*number*	*per cent*
Operator	54	31	57.41	21	38.89	1	1.85	1	1.85
Wife	51	27	52.94	23	45.10	—	—	1	1.96
Children [a]	214	51	23.83	15	7.01	12	5.61	136	63.55

[a] Only children 10 years old and above were included.

A REVIEW: "PERFUMES AND SPICES INCLUDING AN ACCOUNT OF SOAPS AND COSMETICS"[1, 2]

This book is an interesting, comprehensive, and popular treatise on the spices, perfumes, soaps, and cosmetics which we use daily, and which are important in international trade and progress.

Particular attention is given to the element of romance about their source, distribution, and manifold uses, and the process by which they are manufactured. Most of the subject matter is informative and relevant. Without sacrificing accuracy, the author avoids a maze of technical features about the preparation. A comprehensive glossary of all the terms, trade names, flowers, scents, and processes used in the spice, perfumery, and soap industries other than synthetic odors and chemicals is appended. Numerous and unusual sketches of plant specimens and illustrations from photographs are included.

The general scope and method of presentation characterize the author's knowledge in ethnological and archeological sciences. Three qualities have been striven for: a presentation as fluent and readable as is consistent with scientific accuracy of the little-known facts about the most valuable spices in the world; an interesting account of their stories, origin, distribution, and uses in a novel way; and avoidance of technical features of the preparation and agronomical and complete cultural operations of the most interesting and essential spices and perfume-yielding plants.

The author discusses in detail the following subjects: "the romance of spices, a good deed well done, spices and what they are, hot stuff, spices of the New World, the spice that is not a spice, perfumes past and present, perfume side lights, fields of fragrance, what is a perfume, mysterious ambergris, how perfumes are made, synthetic and artificial perfumes, the perfume of the gods, beautifiers and cosmetics, cosmetics and what they are, the dawn of soap, soapy facts, and soap in the making."

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[1] VERRILL, HYATT, A. 1940. Perfumes and spices including an account of soaps and cosmetics, xvi + 304 p., 286 fig. Clinton: Colonial Press, Inc.

[2] General contribution No. 783.

The text as a whole is well adapted to the purpose for which it has been written. The mass of information contained in this book and the readable presentation of the subjects should be of interest to students in agriculture and elementary biology.

PEDRO A. DAVID
Of the Department of Agronomy

COLLEGE AND ALUMNI NOTES

The Rizal Center Fraternity, Los Baños Chapter, held a program and dance at Molawin Hall on June 19 on the occasion of the birthday of Dr. José Rizal.

The officers of the student body for the first semester of the present school year are: president, Rosario M. Orig; vice-president, Bonifacio Niones; secretary, Lelis Loria; treasurer, Nelia Teodoro; representatives to the U. P. Student Council, Ceferino Castelo and Jovito Gallardo; representative to the Philippine Collegian, José Ganacias; representative to the College orchestra, Joaquin Corpuz; representative to the College Cooperative Store, Francisco G. Rentutar; fourteen class representatives; and adviser, Dr. Valente Villegas.

The following papers were read and discussed before the Los Baños Biological Club on June 26:

Mr. J. P. Esguerra. The cost of making tapilan hay.

Mr. F. Barros. Comparative effects of four commercial fertilizers upon the yield of native yellow flint corn.

Dr. G. O. Ocfemia, Mr. Isidro S. Macaspac, and Mr. Hsieh Feng Yuan. A study of canna mosaic and its method of transmission.

Dr. F. O. Santos, of the Department of Agricultural Chemistry, started a study of the foods of the natives of Bontoc, Mountain Province, last summer vacation. He is collaborating with Dr. H. P. Clapp, district health officer.

Lieutenant Ricardo Buhay, who has been Assistant Commandant of the ROTC, University of the Philippines, Los Baños Unit, for four years, was transferred to Camp Murphy on July 5. He was relieved by Lieutenant Elpidio L. Reymundo (Inf.). Lieutenant Cecilio Peñaflor (Inf.) took the place of Lieutenant Melanio F. Perez who was transferred to Camp Henry T. Allen, Baguio. Another loss was occasioned by Sergeant Nemesio Oban who was called back

to active service in the U. S. Army after having been detailed in this College for eleven years. He was succeeded by Corporal Manuel Q. Dacayanan.

A party of Chinese scientists visited the College on June 30 on their way to the United States as fellows of the Rockefeller Foundation to pursue advanced studies in American universities. The members of the party were: Messrs. R. T. Ts'ui and P. H. Frederick Chao, Dr. Merrion Young and Miss Hui-Yin Wang. They were accompanied by Dr. Tomas Gan, of the Institute of Hygiene and Dr. Antonio Isidro, of the College of Education.

The following papers were read and discussed before the Los Baños Biological Club on July 17:

Dr. N. B. Mendiola. Metaxenia, a possible indicator of hidden bud variation in banana as suggested by some fruit abnormalities and pollination experiments.

Dr. A. L. Teodoro. Coco-gasoline as motor fuel.

Mr. Terukichi Abe, rice specialist of the Ohta Development Company, Inc., visited the College on July 26 and conferred with the workers on this crop in the Department of Agronomy.

Mr. Felipe A. Maclang '41, and Mr. Luciano Lactao '41, were recently appointed assistant instructor in entomology and assistant instructor in agronomy, respectively.

Mr. Antonio Flores '34, is teaching vocational subjects at the Sorsogon High School.

The following freshmen who were graduated either as valedictorians or salutatorians from high schools were exempted from the payments of entrance, registration, and laboratory fees in the College for the first semester of the academic year, 1941-1942: Bernardo Q. Ballesteros, Eulalio R. Baltazar, Horacio A. Basco, William L. Fernandez, Felipe Gaxmen, Pedro N. Laudencia, Candido V. Rosario, Pedro R. Sandoval, Filomeno T. Tabayoyong, Nathaniel Tablante, and Francisco Zamora.

THE EXPERIMENT STATION

LIST OF AVAILABLE CIRCULARS

Circular No. 2.—Bud Rot of Coconut (Revised. June. 1934) - - - *By G. O. Ocfemia*

Circular No. 3.—Experimental Errors and Application of the Probable Error to and the Interpretation of Experimental Results - - - - - - - - - - - - - *By Nemesio B. Mendiola* (Published as Chapter IV in *A Manual of Plant Breeding for the Tropics*, 1926, also sold by THE PHILIPPINE AGRICULTURIST at ₱3.25, paper bound, and ₱5.25, cloth bound, in the Philippines, and ₱3.50 and ₱5.50 elsewhere, postpaid.)

Circular No. 5.—Poultry Raising Made Easy (Revised) - - - - *By F. M. Fronda*

Circular No. 7.—How to Produce New Varieties of Gumamela (Hibiscus) - - - - - - - - - - - - *By Nemesio B. Mendiola*

Circular No. 8.—Horse Breeding in the Philippines - - - - - *By Valente Villegas*

Circular No. 9.—Fences for Farm Animals - *By B. M. Gonzalez and J. P. Esguerra*

Circular No. 10.—Practical Directions for Coffee Planting - - - *By Pedro A. David*

Circular No. 11.—The New College Copra Drier—Prepared in the *Department of Agricultural Chemistry* with the cooperation of the *Department of Agronomy and Extension*. (Revised by *Moises M. Kalaw*).

Circular No. 14.—Beriberi: Its Causes and Prevention - - - - - *By F. O. Santos*

Circular No. 15.—Cattle Raising under Philippine Conditions - - *By Valente Villegas*

Circular No. 16.—A Simple Farm Record for the Farmer - - *By Francisco M. Sacay*

Circular No. 17.—College Trapnest - - - - - - - - *By F. M. Fronda and P. S. Paje*

Circular No. 18.—Surveying for Area with a Surveyor's Staff - *By Alexander Gordon*

Circular No. 19.—A Pageant: Illustrating the History and Growth of the College of Agriculture - - - - - - - - - *By Anne F. Cole*

Circular No. 20.—Amount of Nutrients in Philippine Food Materials - - - - - - - - - *By F. O. Santos and S. J. Ascalon*

Circular No. 21.—Cassava Growing and Cassava Starch Manufacture - - - - - - - - - - - *By Nemesio B. Mendiola*

Circular No. 22.—Goat Raising - - - - - - - - - - - - - - *By Valente Villegas*

Circular No. 23.—Curing Pork and Making Sausage for Home Use - - - - - - - - - - - - - - - *By Mariano Mondoñedo*

Circular No. 24.—Construction and Operation of Silos in the College of Agriculture - - - - - - - - - - - - *By José P. Esguerra*

Circular No. 26.—Training Cattle and Carabaos for Work - - - *By Valente Villegas*

Circular No. 27.—Bunchy-top of Abacá - - - - - - - - - - - *By G. O. Ocfemia*

Circular No. 28.—Cotton Culture - - - - - - - - - - - - *By Eulalio P. Baltazar*

Circular No. 29.—Collegiate Education in Agriculture - - - - *By L. B. Uichanco*

Circular No. 30.—What Should Filipino Ornamental Gardens and Ornamental Plants Be? - - - - - - - - - - *By N. B. Mendiola*

Circular No. 31.—How to Slaughter and Dress Farm Animals - - - - - - - - *By Valente Villegas and M. Mondoñedo*

The price of the Circulars listed above is 10 centavos each except Nos. 5, 10, 16, 21, and 30 which cost 20 centavos apiece.

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